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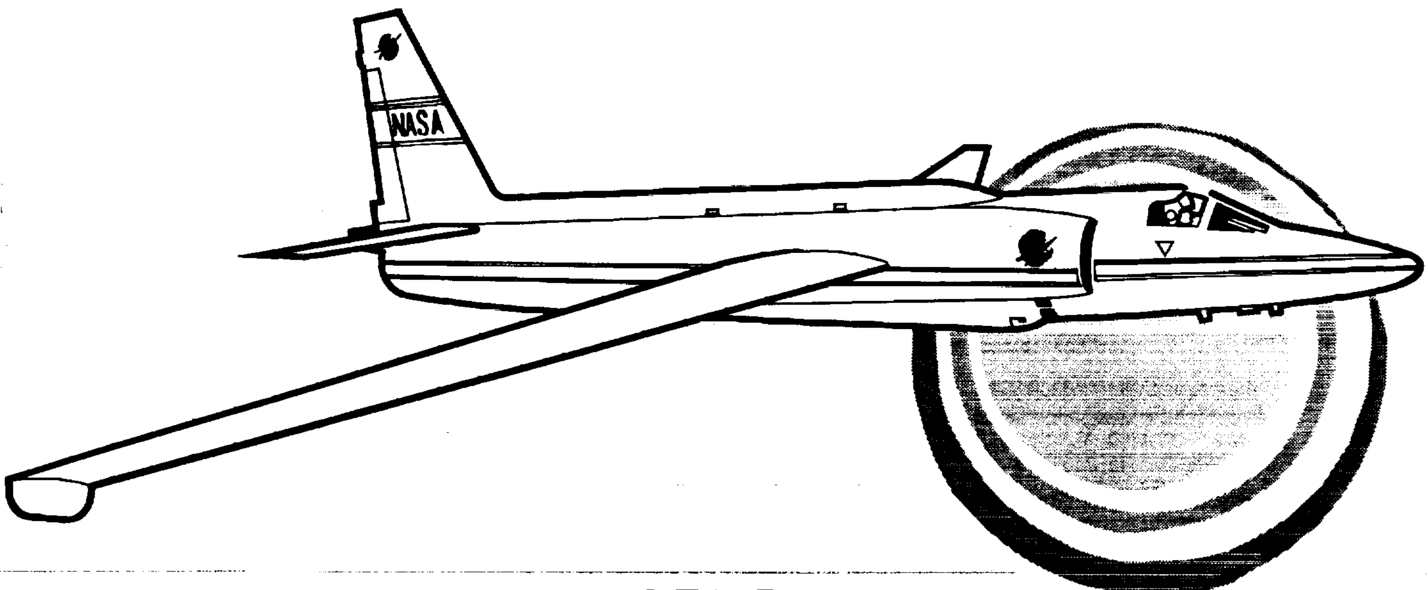

U-2
INVESTIGATORS' HANDBOOK

VOLUME 1

PREPARED BY
AIRBORNE INSTRUMENTATION RESEARCH BRANCH

APPLICATIONS DIVISION

(NASA-TM-101103) U-2 INVESTIGATORS' HANDBOOK, VOLUME 1 (NASA) 72 p

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U-2 INVESTIGATORS' HANDBOOK

INTRODUCTION

The National Aeronautics and Space Administration operates U-2 high altitude airplanes for earth resources survey investigators and also for astronomical, meteorological, and geophysical research experiments. The U-2 is a single-place aircraft with a practical operating range of about 2500 nautical miles over a period of approximately 6.0 hours and a useful equipment bay payload of 500 lbs. Heavier payloads can be accommodated when justified. See Section I, 1.2.

The aircraft are based at the Ames Research Center (ARC), Moffett Field, California. From logistics standpoint the U-2 may only be operated from Moffett Field, with a complete staging capability at Wallops Island, Virginia. Strong justification is required to provide ground support to operate from another base.

The purpose of this handbook, Volumes 1 and 2, is to acquaint existing and potential investigators with the U-2 and its capabilities. Volume I covers the airplane and outlines the requirements for equipment design and installation. Volume 2 describes existing Airborne Instrumentation Research Project (AIRP) sensors.

As new aircraft modifications and sensor changes occur, replacement sheets will be mailed to recipients of the handbook; hence the loose leaf format.

Our most severe operational problem has been the failure of investigators to follow the design and construction requirements imposed by accepted flight safety standards. The reader's attention is called particularly to Sections V and VI of this handbook.

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LIST OF FIGURES

SECTION I

AIRCRAFT PERFORMANCE

1.1 Basic Aircraft Performance

The U-2 (Figures 1.1 through 1.7) is a single-place aircraft designed for high altitude, long range operation. It is powered by a single jet engine. The aircraft is of all metal construction and is characterized by its long wings, two-wheel bicycle landing gear and droppable auxiliary gear (pogos) located outboard under each wing. It carries a pilot, a normal payload of up to 500 lbs in the equipment bay, up to 2500 nautical miles for approximately 6.0 hours.

The following subsections summarize the aircraft specifications and performance:

1.1.1 Airplane Range:

Normal range is up to 2500 nautical miles over a period of approximately 6.0 hours.

1.1.2 Airplane Altitude:

For NASA experiments, the U-2 is normally flown at a constant altitude of 65,000 ft. Other altitudes may be arranged, if compatible with the airplane capability.

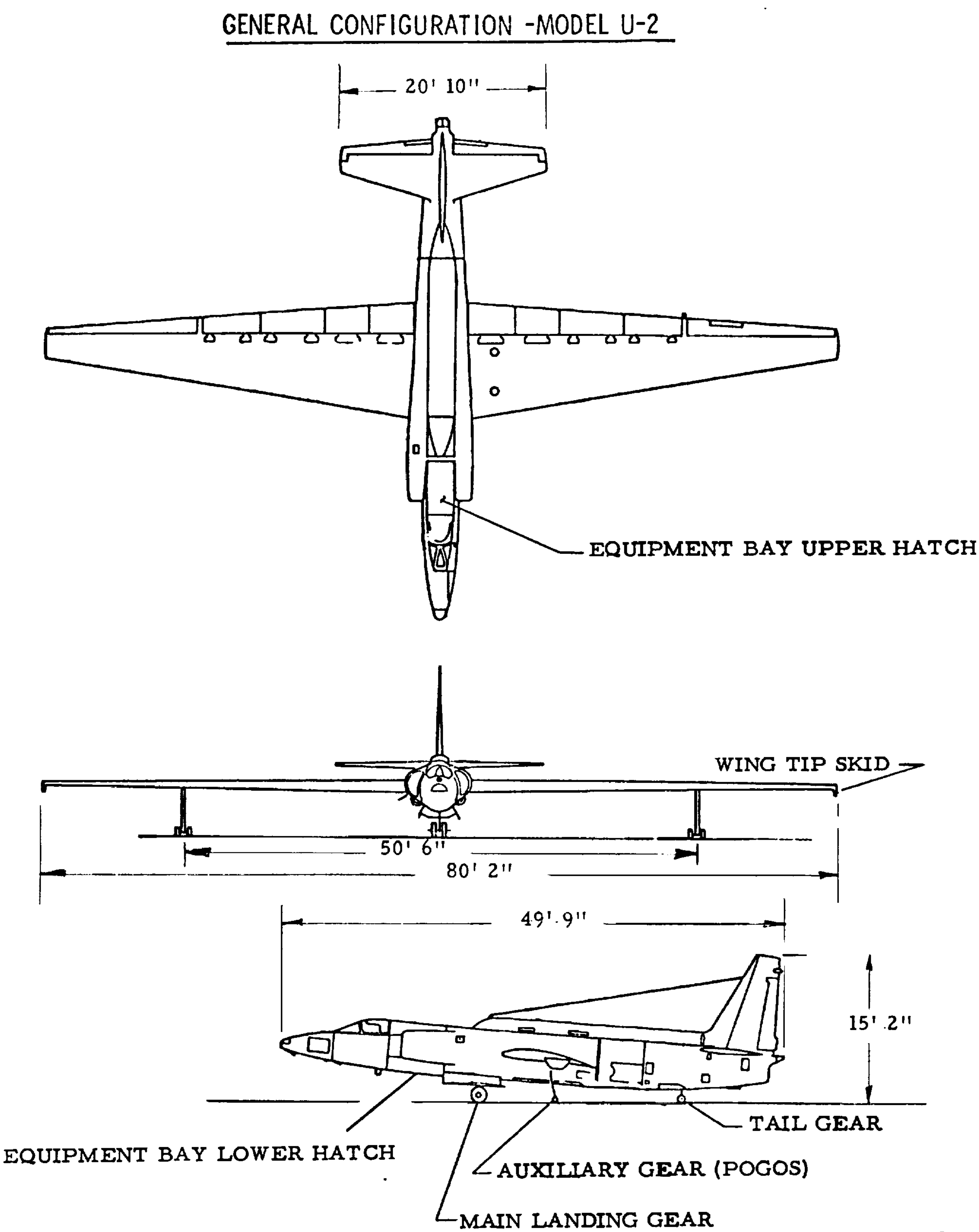

GENERAL CONFIGURATION -MODEL U-2
20' 10"
EQUIPMENT BAY UPPER HATCH
WING TIP SKID
50' 6"
80' 2"
49'.9"
15'.2"
TAIL GEAR
EQUIPMENT BAY LOWER HATCH
AUXILIARY GEAR (POGOS)
MAIN LANDING GEAR

Figure 1.1

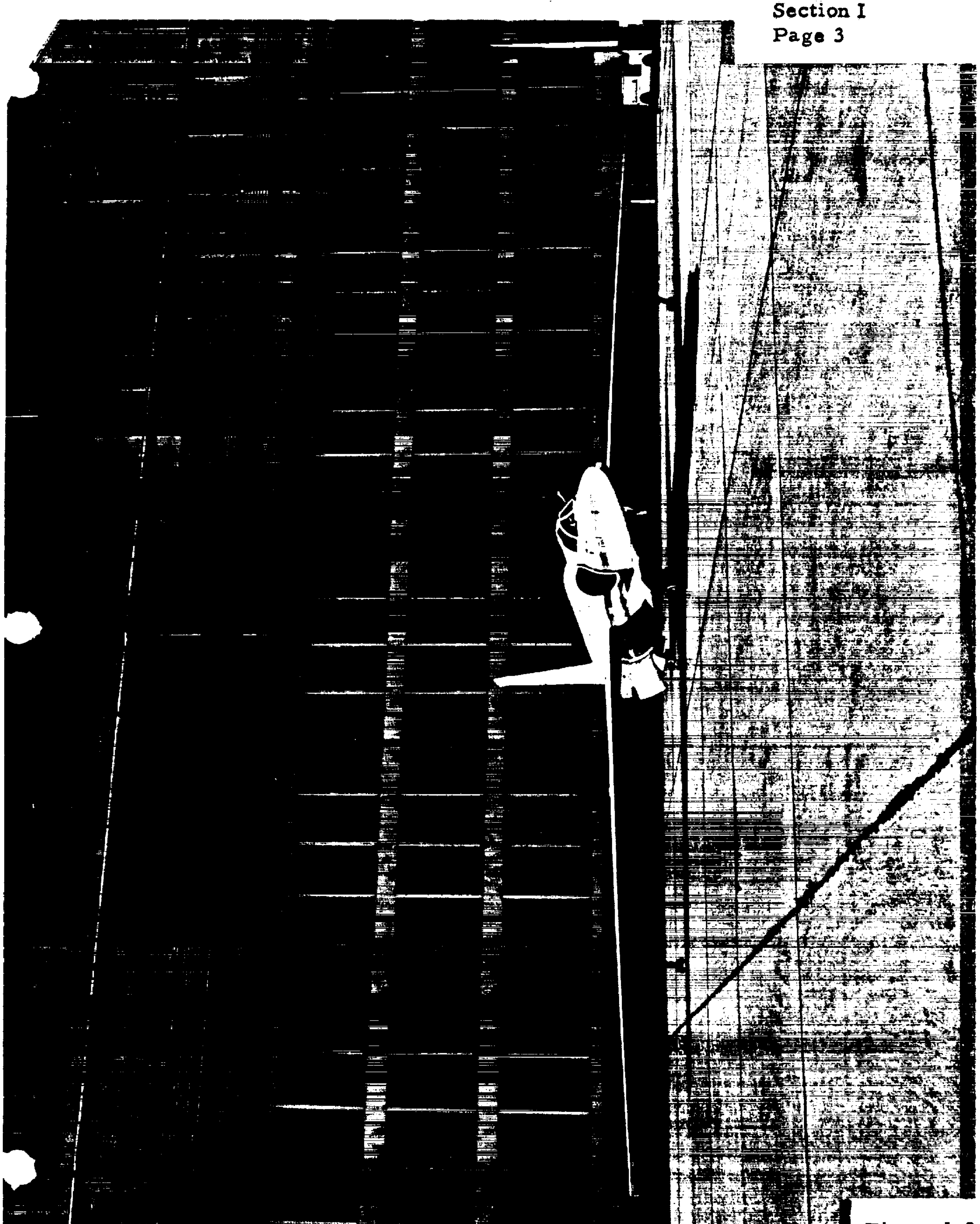


Figure 1.2

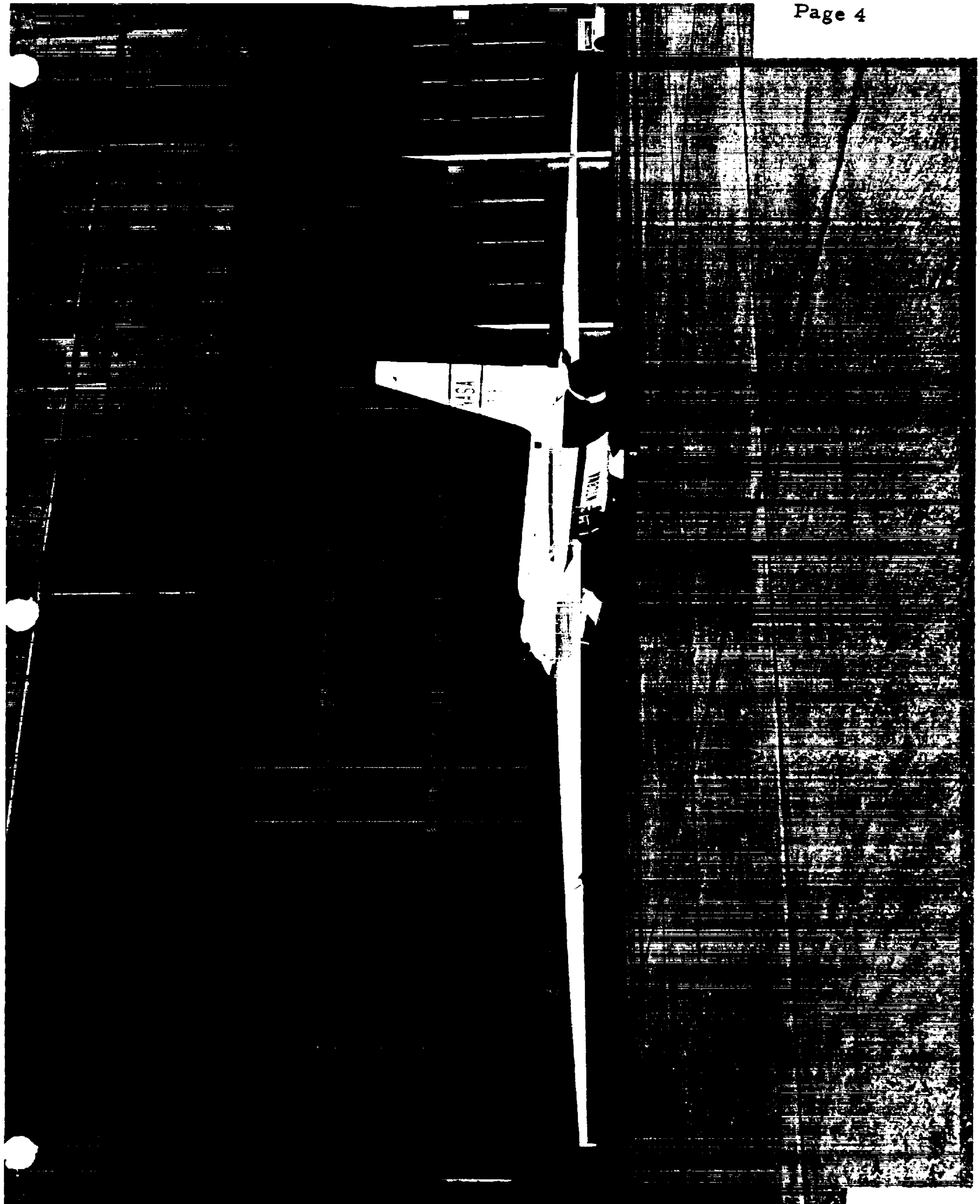


Figure 1.3

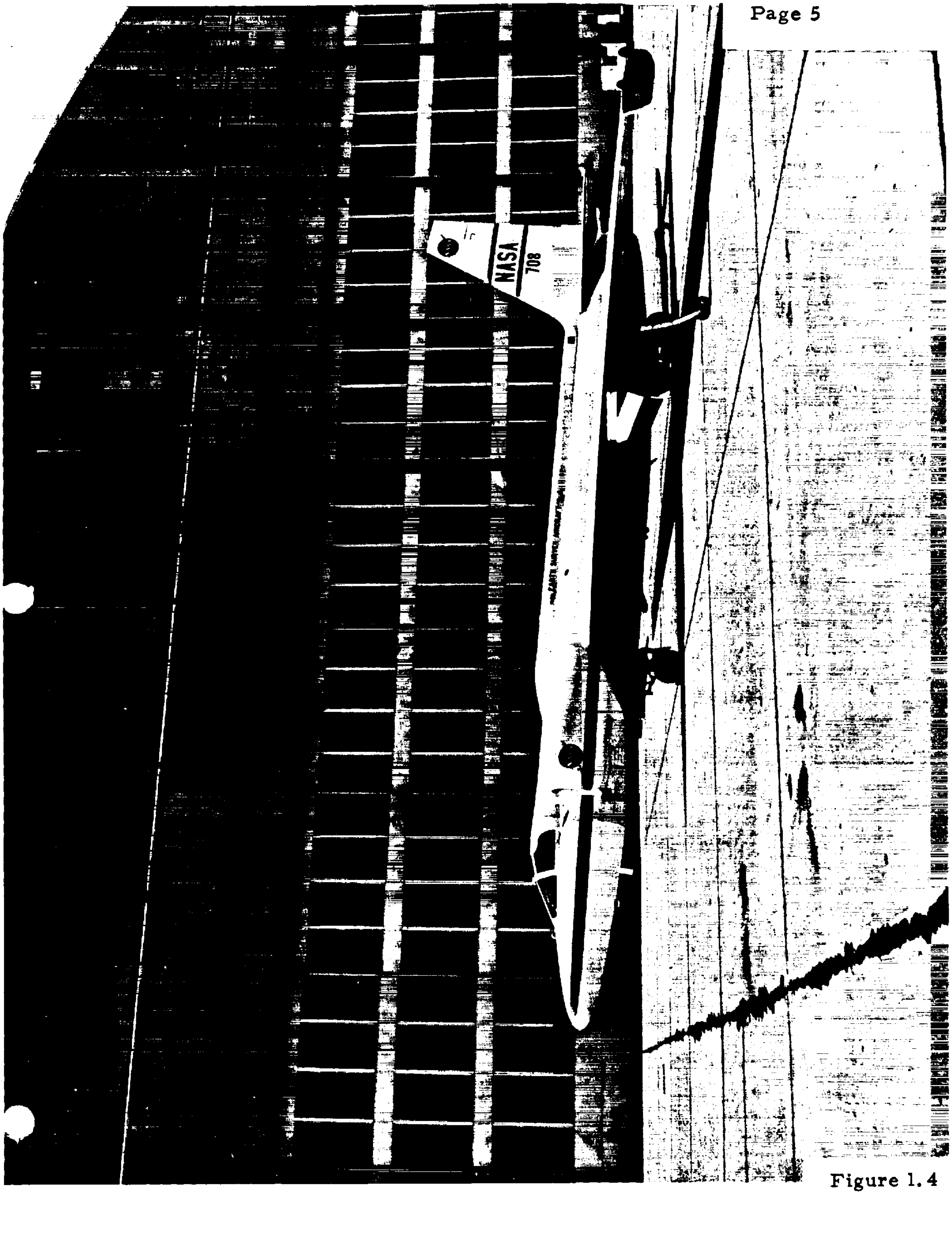


Figure 1.4

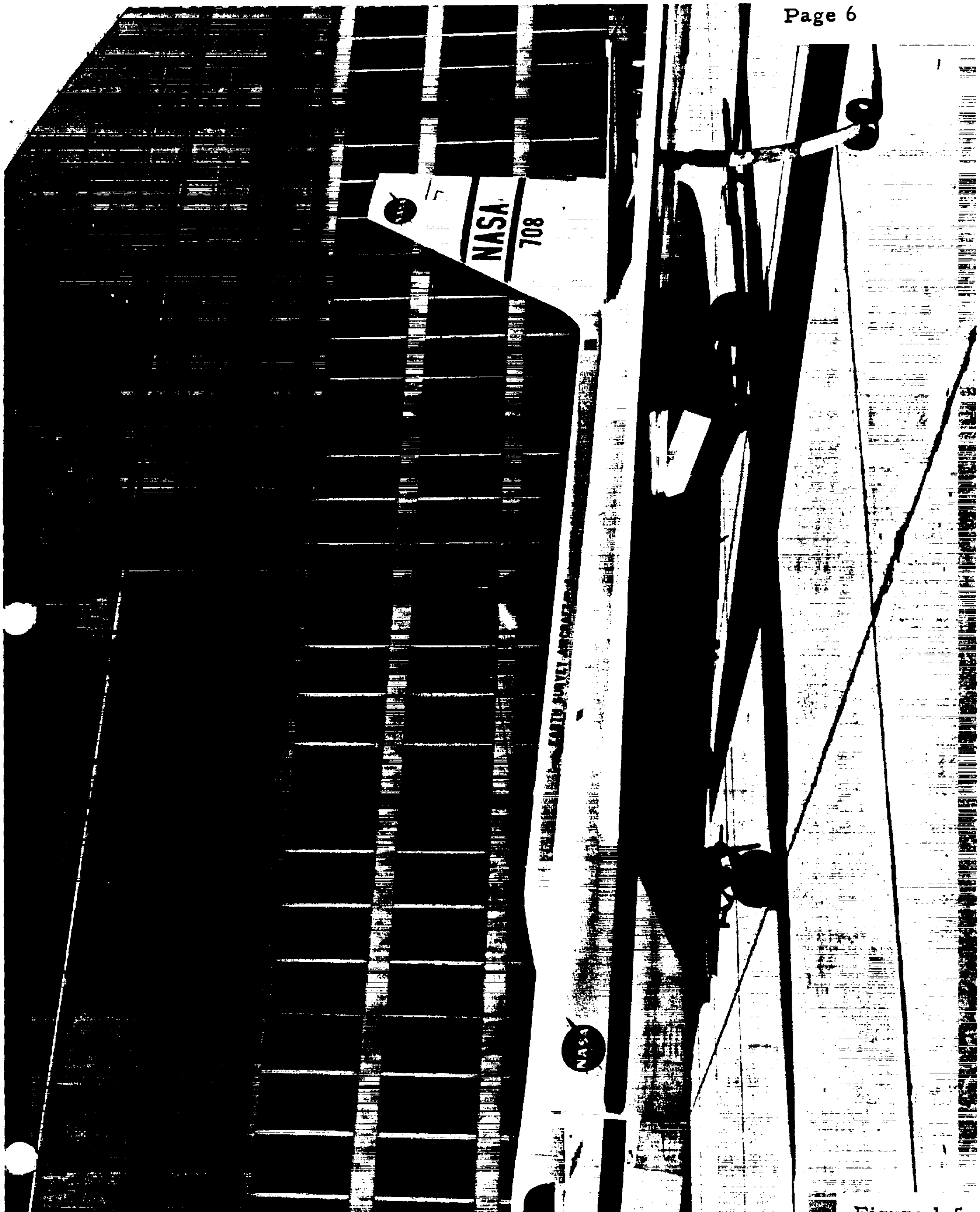


Figure 1.5

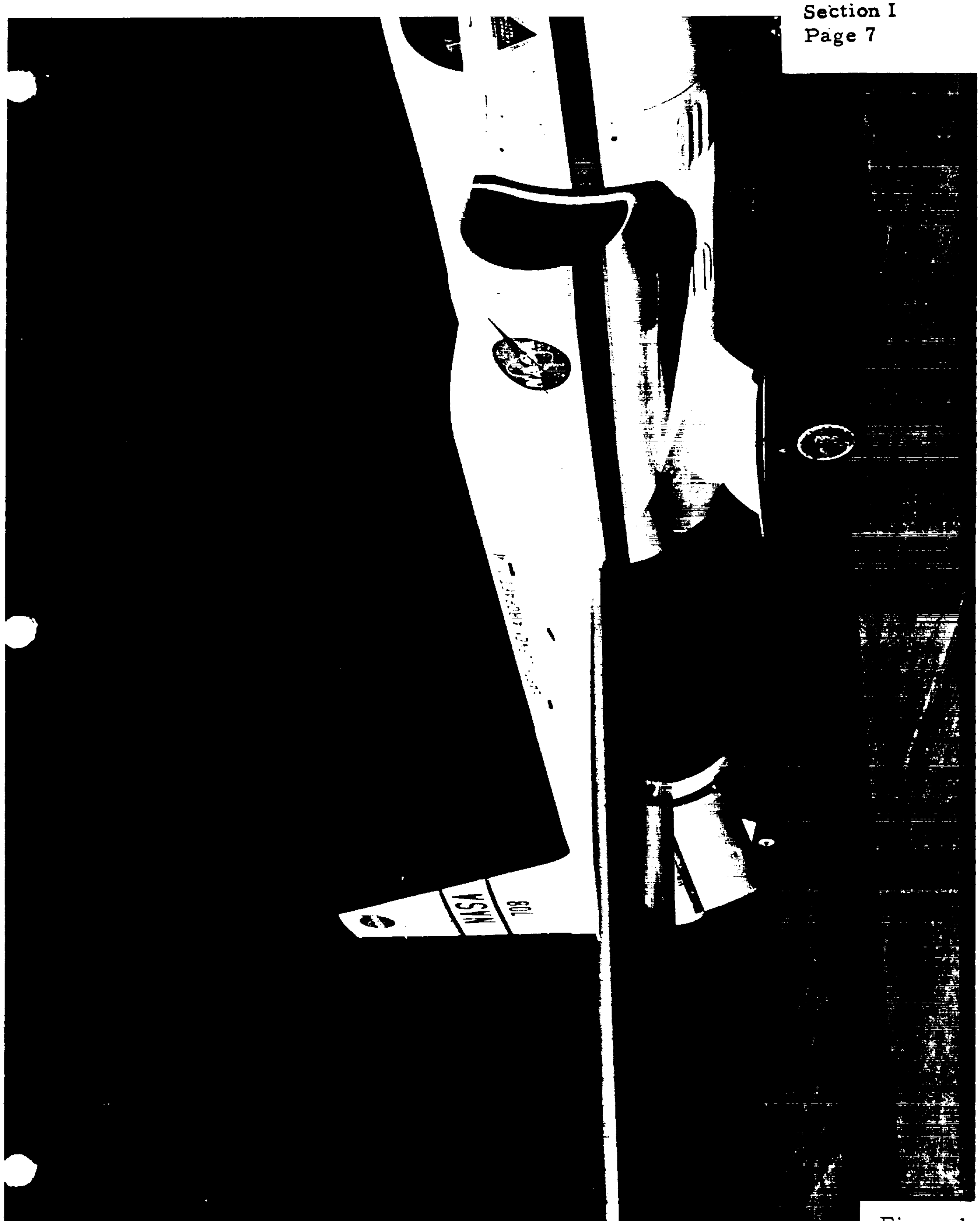


Figure 1.6

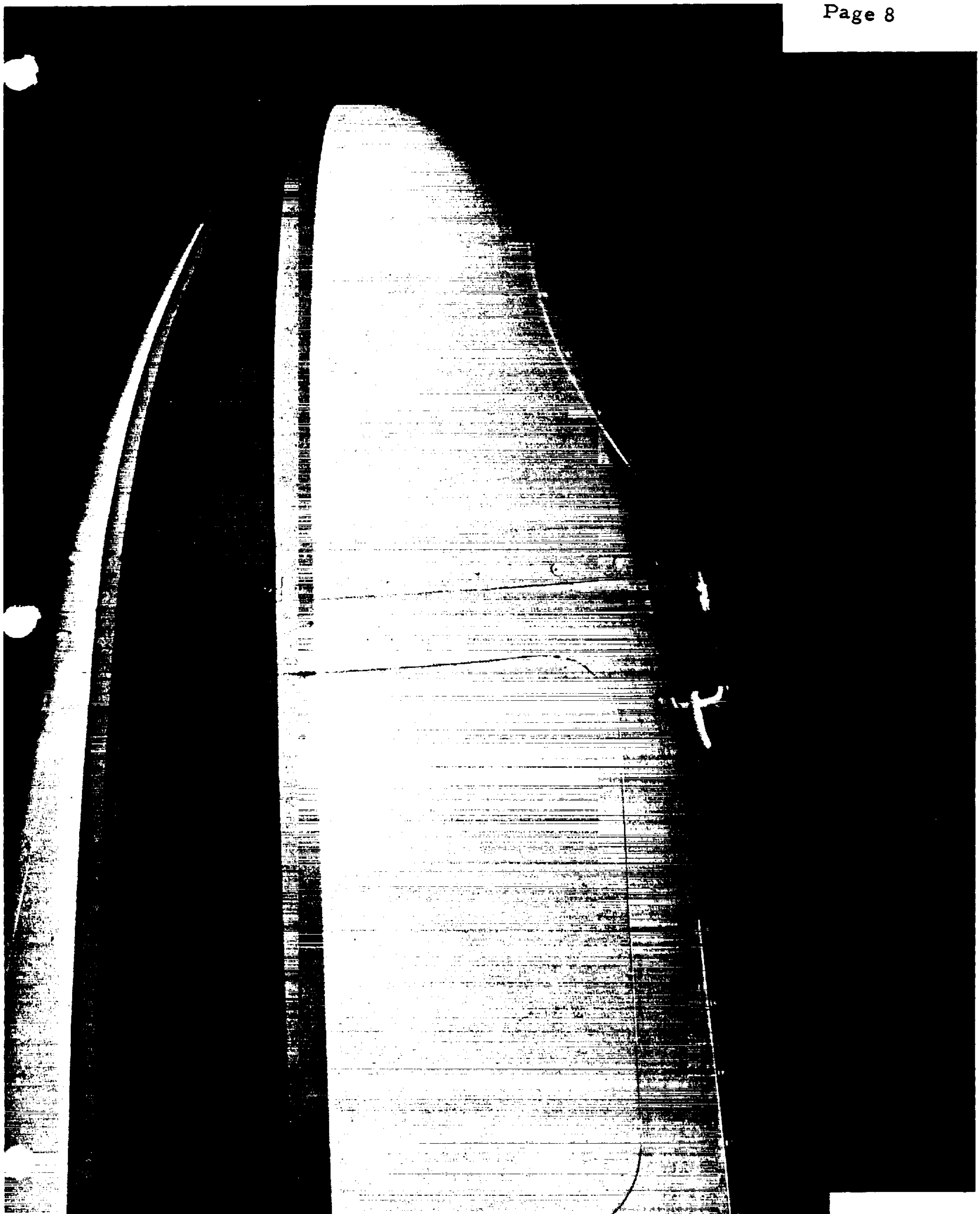


Figure 1. 7

1.1.3 Cockpit and Equipment Bay Air Conditioning Pressurization and Temperature:

Air conditioning and pressurization air is ducted directly into the cockpit. From the cockpit it flows through a pressure regulating valve into the lower front end of the equipment bay. Air is then exhausted overboard through a pressure regulating valve located at the top of the aft bulkhead in the equipment bay.

The equipment bay altitude varies with aircraft altitude up to 30,000 ft pressure altitude and all equipment installed in this area must be capable of sustained operation at a 35,000 ft pressure altitude. Equipment installed at other locations on the airplane must be qualified for sustained operation up to 100,000 ft.

The equipment bay temperature depends upon the temperature of the invoming air, from the cockpit, and upon the heat output of the equipment bay package. Local temperature in the bay is also affected by the size and shape of the package as these affect air circulation. Heat is carried out of the equipment bay by air flow and by heat transfer through the airframe. Normal air flow out of the equipment bay is 31bs/min.

The following figures indicate the range of temperatures to be expected during cruise with an average* heat load:

Lower portion	$41^{\circ}F$ to $50^{\circ}F$
Upper portion	$59^{\circ}F$ to $77^{\circ}F$

*These temperatures can very considerably as a result of the heat load produced by the specific experiment under consideration for installation.

1.2 Experiment Installations

The experimentor should review Section V and Section VI of this Handbook regarding experiment installation guidelines.

Experiments may be installed in the following areas on the airplane:

a. Equipment Bay

Experiments in this area shall be installed on an equipment rack designed and fabricated by Lockheed. Any changes to this rack by the experimentor shall be submitted to Lockheed for a stress review prior to accomplishment of the change.

Installation in other areas of the equipment bay shall only be accomplished by Lockheed to modify structure to accept the experiment.

b. Canoe Area

Installations in this area shall only be accomplished by Lockheed to modify structure to accept the experiment.

c. Wing Pylon/Fuel Tank Area

Installation in this area shall only be accomplished by Lockheed to modify structure to accept the experiment. The location of "hard points" have been designated for use in mounting equipment within the wing tank. (See Figure 1.8)

1.3 Installation Weights

Maximum payload weights are subject to limitations for hatch and rack mounted experiments. An additional limitation is imposed by rack and hatch existing designs as noted.

Equipment Bay Area	750# maximum
Canoe Area	100# maximum
Wing Pylon/Fuel Tank Area	300# maximum in each tank

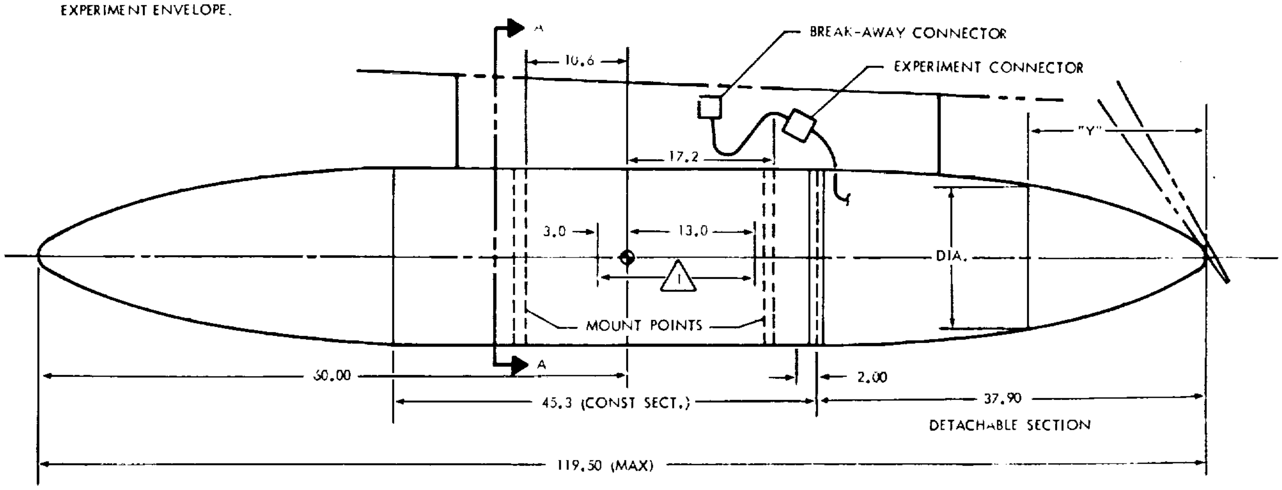
"Y"	5.00	10.50	14.0	18.0	24.0	30.0	35.0	36.3
DIA.	6.23	10.07	11.94	18.74	15.51	16.6	17.41	17.60

NOTE: THIS TABLE APPLIES TO NOSE SECTION ALSO. DIMENSIONS SHOWN ARE MAXIMUM FOR THE EXPERIMENT ENVELOPE.

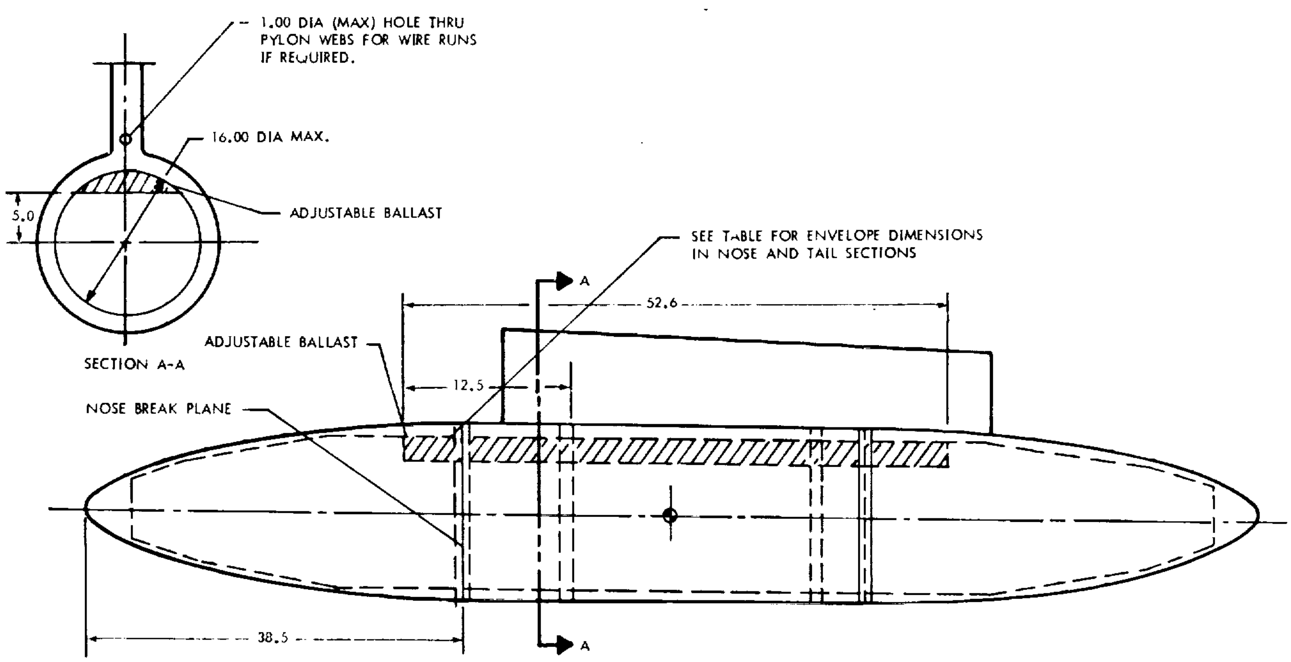
NOTE: 1 CENTER OF GRAVITY OF EXPERIMENT WEIGHT WILL BE HELD WITHIN LIMITS SHOWN.

MAXIMUM WEIGHT OF ENTIRE EXPERIMENT INCLUDING EXPERIMENT, EXPERIMENT STRUCTURE, ELECTRICAL HARNESSES AND BALLAST FOR TANK, SHALL NOT EXCEED 300 POUNDS.

2 ALL MODIFICATIONS TO TANK REQUIRED TO ACCEPT EXPERIMENT PACKAGES SHALL BE DONE BY L.A.C.



WING TANK DIMENSIONS



WING TANK CONFIGURATION (SEE NOTE #2)

FIGURE 1.8

When an equipment bay upper or lower hatch is modified to accommodate an experiment, the following weight limitations shall apply to the weight added to the original hatch configuration and shall be considered as part of the Equipment Bay Area weight.

Hatch Type	Allowable Additional Weight
Equipment Bay Upper Hatch (P/N EAQ110)	30# maximum
Equipment Bay Upper Hatch (P/N EAQ119)	300# maximum
Equipment Bay Lower Hatches	430# maximum

Further, for equipment rack mounted experiments the following paylaod limitations shall apply:

Rack Type	Maximum Payload
EAQ1-1 Rack Assembly	429#
(Rack weighs 21# and is in addition to payload limit)	
EAQ1-500 Rack Assembly	477#
(Rack weighs 23# and is in addition to payload limit)	

NOTES: 1. When an experiment is installed in a wing tank, the opposite tank shall be loaded with ballast to equal the total experiment weight in the other tank. In addition, in the interest of pilot safety, a tank jettison circuit is installed into each pylon for use by the pilot in cases of an emergency that would dictate wing tank ejection.

2. When wing pylon tanks with fuel or an experiment are installed on the wing, slipper type fuel tanks shall not be installed due to weight and structural limitations.

The above listed weights are maximum allowables and shall include the following items as part of the total experiment weight:

a. Experimentor's equipment including consumables.

b. All structure such as equipment racks, brackets and any other structure added to the experiment to support the equipment, including hatch modifications.

c. Experiment wiring and wiring supports, plugs, control panels, power junction boxes, etc.

d. Any ballast required to trim the aircraft for proper weight distribution. It is especially important that all experiments be coordinated with Lockheed in the early planning stages to ascertain the need and placement of ballast to assure proper weight distribution and to determine actual experiment maximum allowable weight.

1.4 External Configuration/Contour Control

Due to the critical aerodynamic characteristics of the U-2 airframe, an experiment that would require a change in existing airplane contours will be evaluated on an individual basis for aerodynamic effect. The wing pylon/fuel tank contours shall not be modified due to the proximity of the lower wing surface.

1.5 Frequency of Flights

The frequency of flights on the NASA U-2 depends primarily on pilot and ground crew availability. Maximum effort schedules should not exceed 6.0 flight hours per 24-hour period, 26 flight hours per week, or 100 flight hours per month. There are also practical limitations for aircraft maintenance during normal working hours. The justification for heavy scheduling, maximum effort, is always carefully scrutinized.

1.6 Aircraft Stability

An autopilot controls attitude and heading. Rates with and without autopilot, at least 90% of the time, are less than as follows:

	Rate (milliradians/sec)		Period (seconds)	
	With A/P	Without A/P	Range	Most Common
ROLL	± 4.5	3 to 7	2 - 5	4 - 5
YAW	± 2.66	1.5 to 7	2 - 5	3 - 5
PITCH	± 3.33	3 to 7	4 - 6	5

1.6.1 Bank Angles

A bank angle of 12° and .58 degrees/sec turn is normally used.

1.6.2 Angle of Attack Attitude During Cruise

The variation of the fuselage reference line (WL 100) varies, during fuel burn off, from nose up 2.5° to nose down 1.0°.

1.6.3 Vibration

The U-2 is relatively free of engine generated noise. Inflight vibration measurements due to engine roughness indicate frequencies between 80 - 110 cycles per second and the maximum double amplitude (measured vertically) to be less than .001 inch. The predominant airplane frequency is 95 to 100 cycles per second. Operations out of air fields with rough taxi-ways and runways have (in actual operation) imposed the most severe shock loading on the aircraft and its equipment, and should be considered during investigators' equipment design phase.

SECTION II

RADIO COMMUNICATION AND NAVIGATION

2.1 Basic Equipment and Frequencies

The U-2 aircraft is equipped with (HF) and (UHF) communications and radio navigation systems. Navigation aids include TACAN, TACAN-derived area navigation system (R-NAV), VHF omnidirectional bearing (VOR/ILS) low frequency automatic direction finding (ADF) and an ATC Transponder. All communications and navigation equipment are set and controlled in the cockpit.

2.1.1 Frequencies and Interference

Investigators should engineer their equipment to prevent spurious response at these frequencies and to limit any output from their systems. An engineering analysis or assessment shall be made to determine the magnitude and effect of any interferring signals or noise generated by the equipment and its installation being proposed. The magnitude and effect of these signals or noise to the onboard radio and radio-navigation systems shall have no significant effect on their proper use and/or operation. The frequency ranges of the various radio, radio-navigation and ATC equipments are listed below:

ADF Frequency	.19 to 1.75 MHz
High Frequency	2.0 to 30 MHz
Very High Frequency	108 to 152 MHz
Ultra High Frequency	225 to 400 MHz
ATC Frequency	1030 and 1090 MHz
TACAN Frequency	962 to 1213 MHz

2.2 Navigation

2.2.1 The primary airborne navigation equipment for the U-2 aircraft is provided by the TACAN-derived area navigation system (R-NAV). Steering information to preselected waypoints is provided to instrument panel indicators by means of bearing, distance, heading, range and course data. An R-NAV control panel display, in the cockpit, indicates current airplane position and provides a means for changes in flight track, enroute.

Airplane location accuracy will be within ± .5 nautical miles. It is mainly dependent on the geometry of the TACAN stations.

2.2.2 An additional navigational aid is provided by the optical view sight system which provides visual coverage of the area below the aircraft (lower hemisphere).

2.2.3 In addition to the above, VOR/ADF navigational aid equipment is utilized enroute to the specific area of interest. The U-2 aircraft when flown in the Mach Hold mode is a constant Mach speed aircraft, and by dead reckoning, navigation can therefore be plotted as a function of time, speed and heading. Meteorological data for area of interest would provide winds and temperature at altitude for a more accurate flight profile.

SECTION III

ELECTRICAL POWER

3.1 Summary Specifications

3.1.1 Investigators' Power

The basic specifications for investigators' power are as follows:

A. 380 to 420 Hz, 208/120 ± 5 volts, 3-phase wye connected, 5.5 KVA available for experiments. Phase rotation is ABC.

B. 28 VDC ± 1 volt, 80 amperes available for experiments.

3.2 Aircraft Power Source and Frequency Converters

The basic power sources consist of one engine driven 28 VDC generator rated at 225 amperes and one hydraulic 208/120 volt, 400 Hz, 3-phase alternator rated at 7.5 KVA. Two airplane 115 volt, 3-phase, 400 Hz, 750 VA inverters and one 115 volt, 3-phase, 400 Hz, 100 VA inverter are powered by the 28 VDC generator and by the airplane battery during emergency conditions. These three inverters supply aircraft systems only and are used if the main hydraulic alternator fails.

There are no provisions aboard the airplane for 60 Hz power and any requirements for this type of power must be coordinated in advance of preceeding with design.

AC power is supplied from the 3-phase 208/120 volt wye connected alternator with a grounded neutral. Voltage regulation is ± 5 volts and is not dependent on engine speed.

DC power is supplied to maintain a bus voltage of 28 $\pm$ 1.0 volt. Ripple voltage is 1 volt maximum peak-to-peak; however, transient voltages within the power parameters defined by MIL-STD-704B may occur. No protection is provided for over voltage. System circuit breakers are provided for protection of aircraft wiring only and are not intended to protect equipment.

All aircraft electrical power meets requirements of MIL-STD-704B and all utilizing equipments shall also meet these same requirements.

3.3 Trunk Lines

Two electrical cables or trunk lines, are provided between the cockpit control panels and the forward bulkhead of the equipment bay for the electrical control of equipment bay mounted packages. A maximum of 37 unshielded wires are available in one trunk line and 39 wires of which 21 are shielded in the second trunk line.

3.4 Wing Tank Experiment Trunk Lines

One electrical trunk line of twenty-two (22) wires is permanently installed in each wing for wing tank mounted experiments.

The following wiring is provided:

- 115V 400 Hz 3-phase at 7.5 amperes/phase.
- 1 28 VDC bus at 10 amperes.
- 1 Control wire from the cockpit (+28 VDC).
- 2 Ground wires.
- 1 Set of 3 conductor twisted (3 wires).
- 2 Sets of 3 conductor twisted/shielded (6 wires).
- 2 Sets of 2 conductor twisted/shielded (4 wires).
- 2 Spare single conductor wires.

A standard receptacle is mounted in each tank pylon. The mating connector (Cannon Part Number CA3106RX28-11P or MS83723-24R2811N plug and MS83723-34N28 Backshell) is to be provided as part of the experimentor package.

SECTION IV
EQUIPMENT BAY

4.1 Equipment Bay

A special equipment bay, located just aft of the cockpit, is the principal location for special equipment packages. This bay, called the Q-Bay, has top and bottom hatches which are quickly removable by means of external latches. See Figure 4.1.

Figure 4.2 shows the equipment bay, from above, looking aft. Figure 4.3 shows the equipment bay, from above, looking forward. Installation of packages is normally accomplished by lifting them from the bottom through the lower hatch opening. Clearance under the airplane for rolling packages underneath the equipment bay is shown in Figure 4.4.

Several attach points are provided in the bay so that packages of almost any shape can be readily mounted. For arrangement, location and loading of the attach points, see Figure 4.5. Figure 4.6 gives lower fuselage contours in the equipment bay area.

No modifications to the side primary structure between the upper and lower longerons will be permitted.

An assortment of lower equipment hatches which may be used are shown in Figure 4.7 through 4.24. It should be noted that the F845 Hatch (Figure 4.22) is a modified version of the F151 Hatch (Figure 4.8), both of which are available for approved experimental programs.

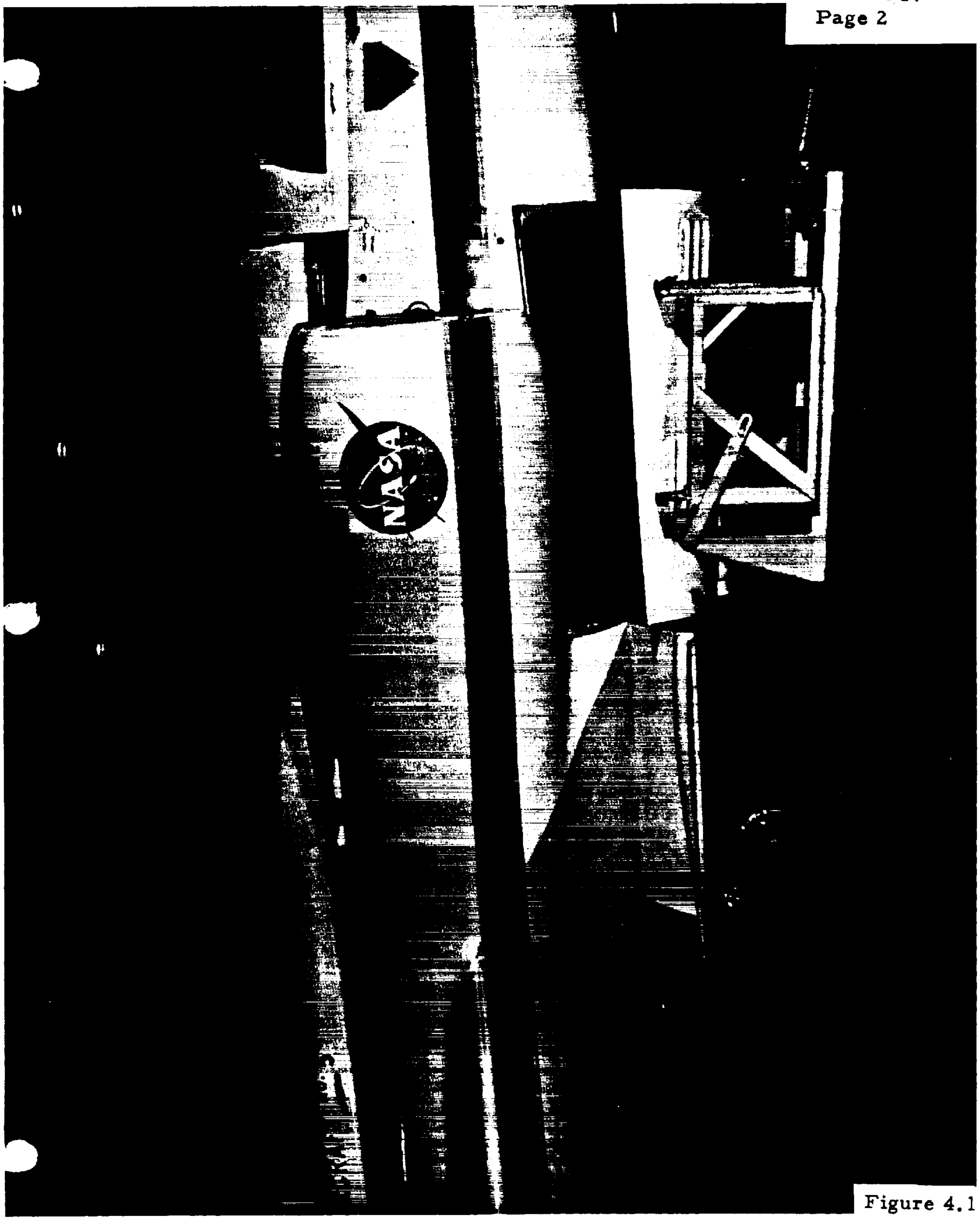


Figure 4.1

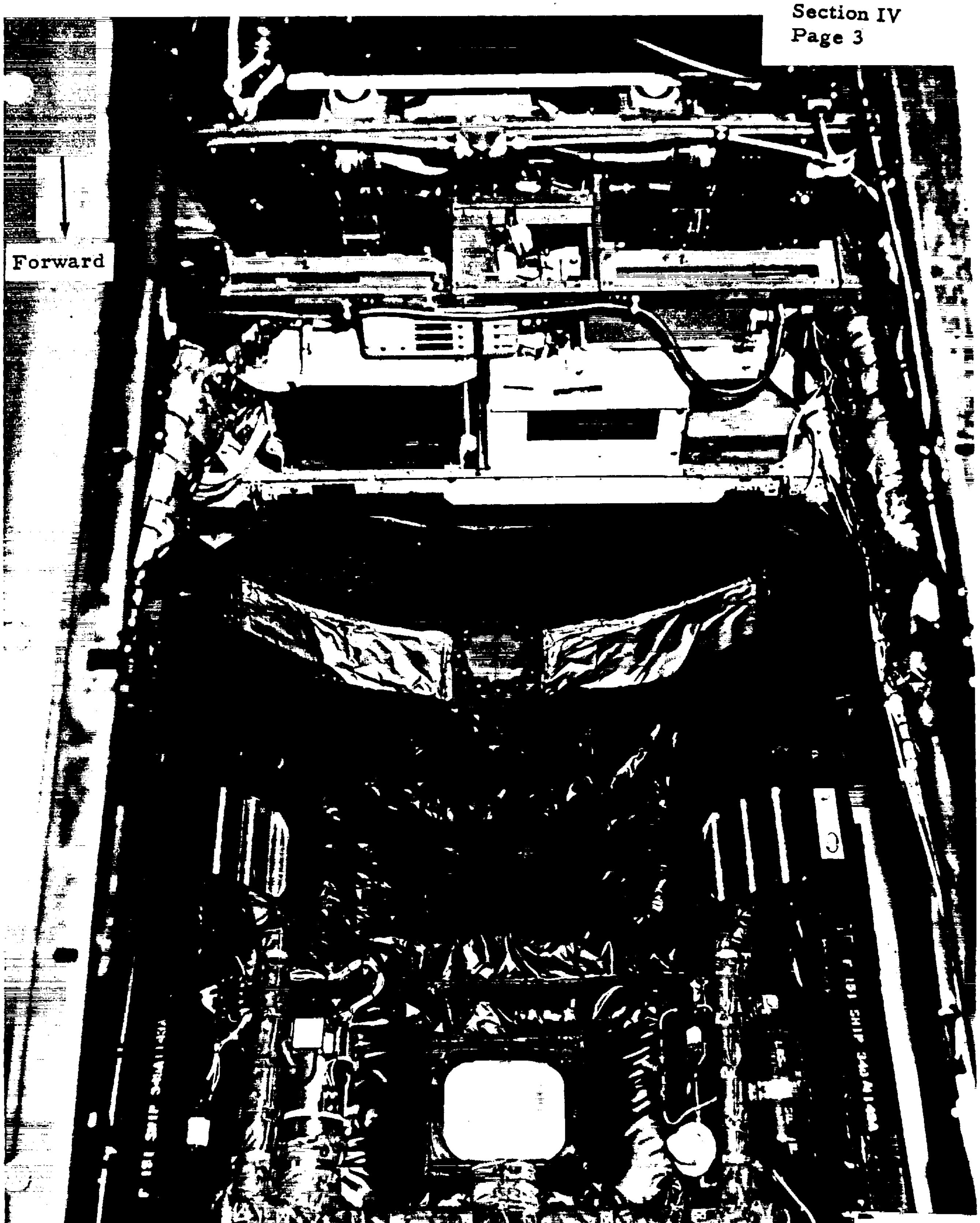


Figure 4.2

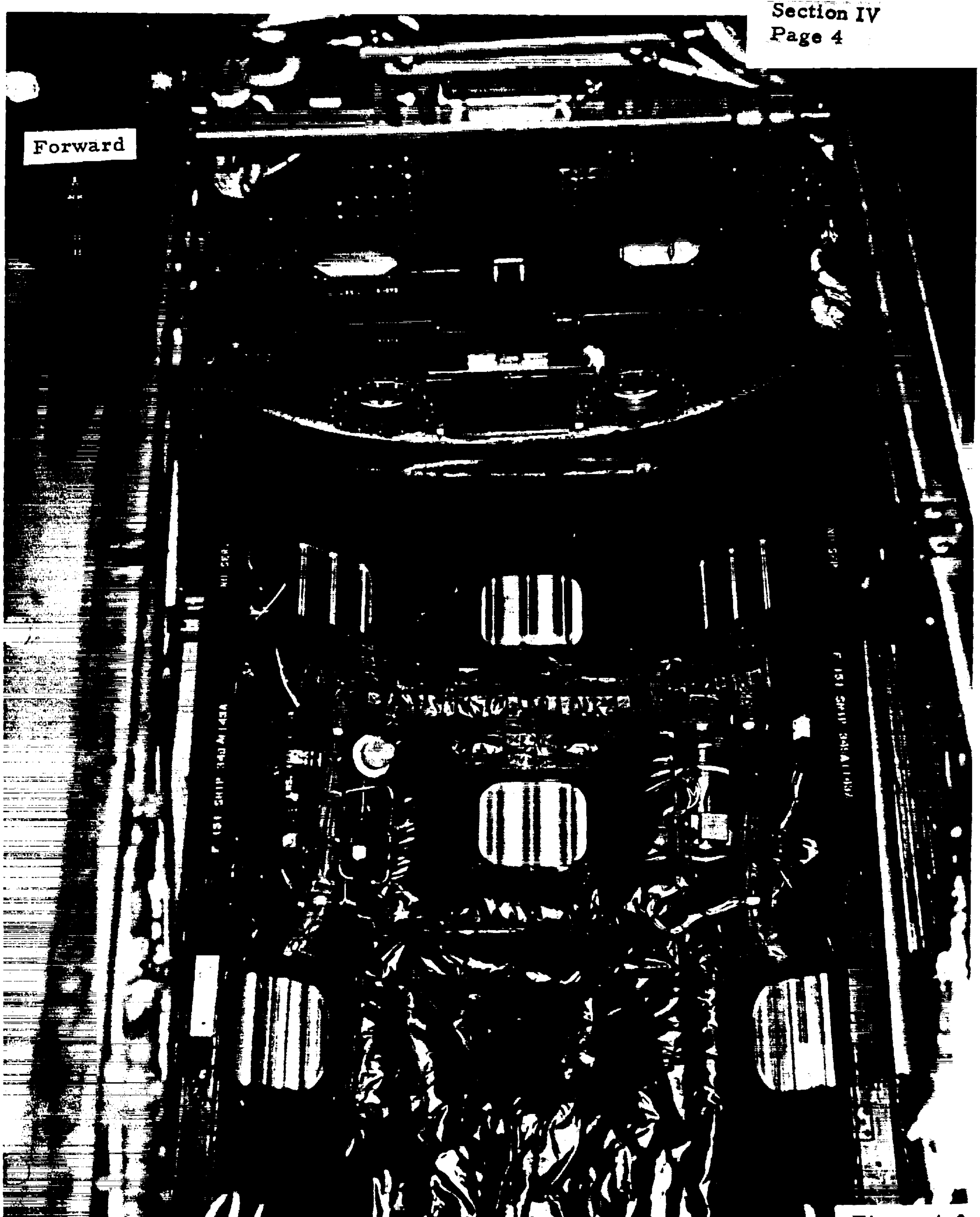
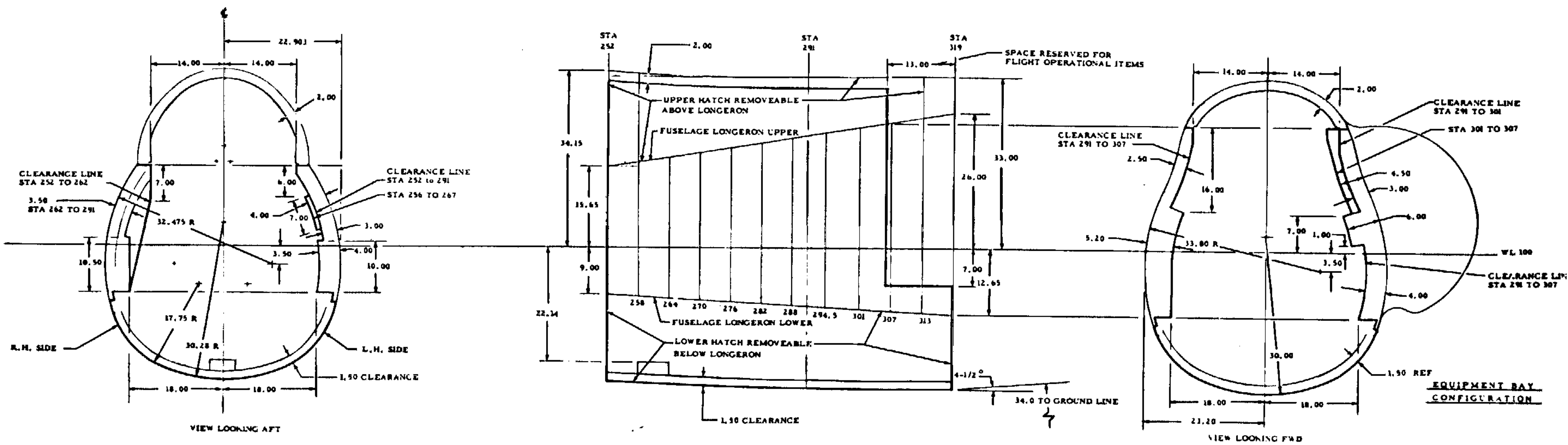
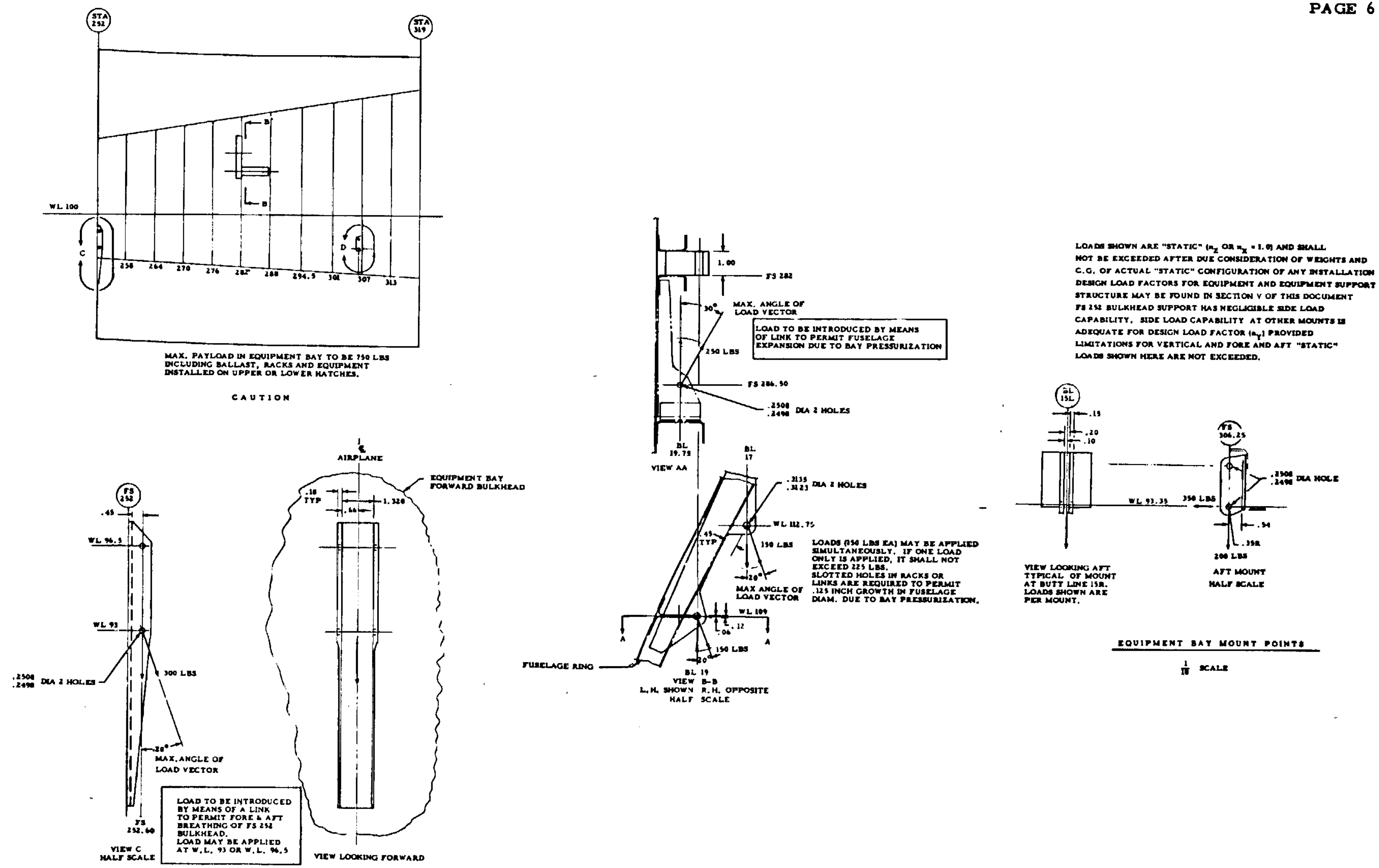


Figure 4.3



EQUIPMENT BAY CONFIGURATION

FIGURE 4.4

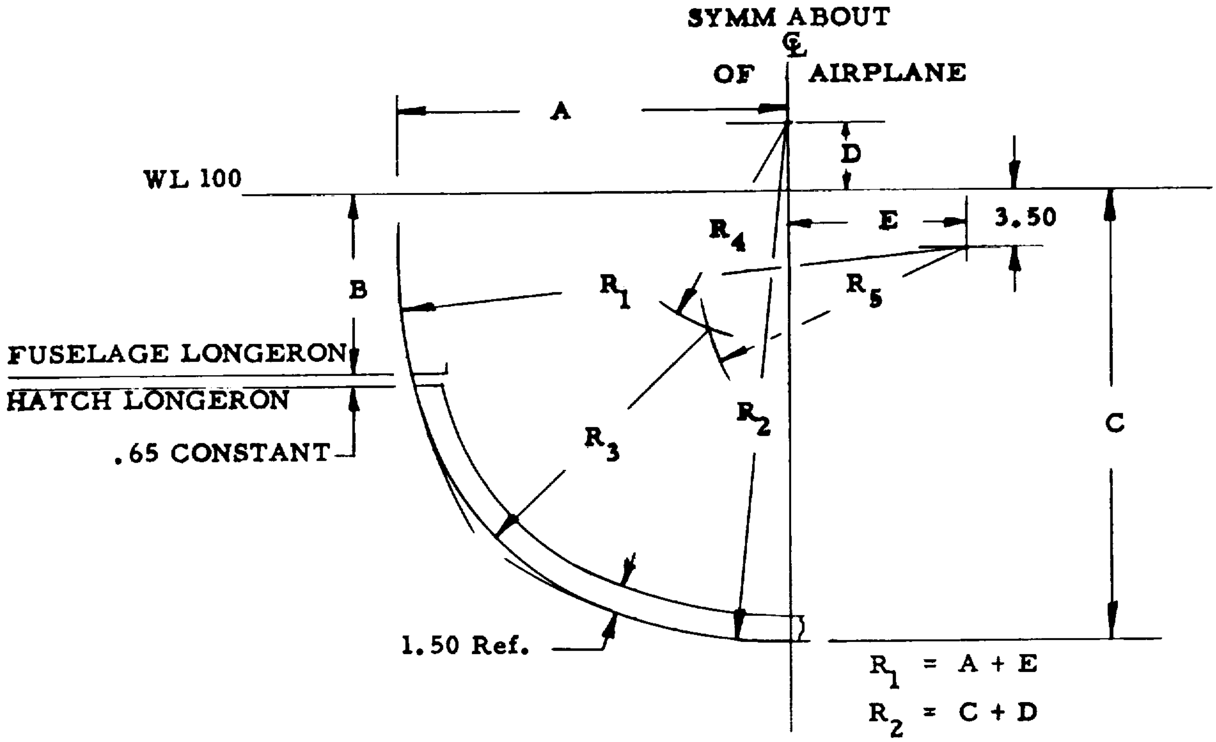


EQUIPMENT BAY MOUNT POINTS

$\frac{1}{10}$ SCALE

FIGURE 4.5

LOWER FUSELAGE CONTOURS
(EQUIPMENT BAY)
F. S. 252 - 319



R_1 = A + E

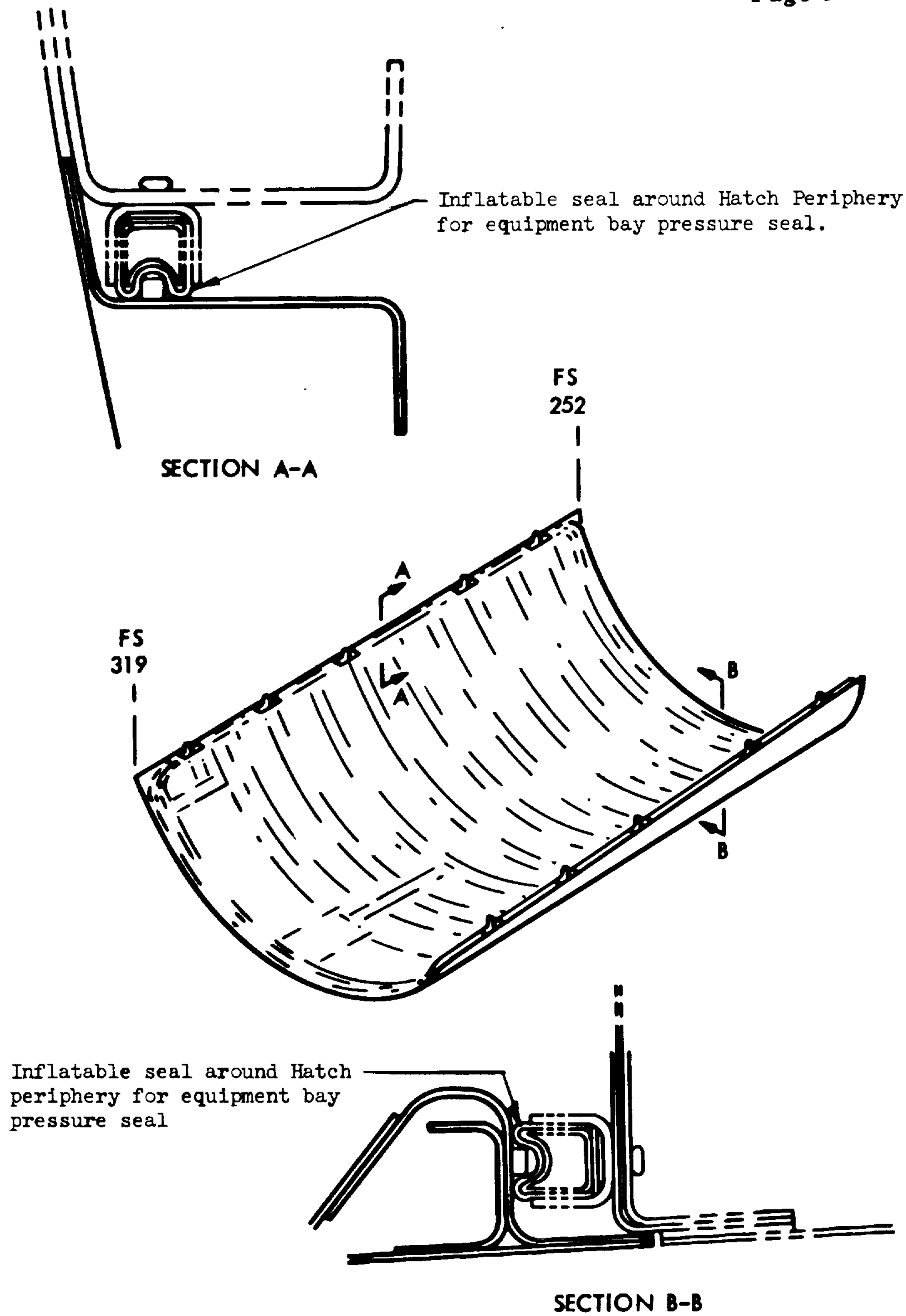
R_2 = C + D

R_4 = R_2 - R_3

R_5 = R_1 - R_3

STA	A	B	C	D	E	R_1	R_2	R_3	R_4	R_5
252	22.903	9.00	25.861	4.419	9.572	32.475	30.280	17.750	12.530	14.725
258	23.054	9.327	26.111	4.872	9.983	33.037	30.983	17.750	13.233	15.287
264	23.152	9.654	26.330	4.987	10.362	33.514	31.317	17.750	13.567	15.764
270	23.197	9.981	26.518	4.844	10.583	33.780	31.362	17.750	13.612	16.030
276	23.200	10.307	26.675	4.522	10.600	33.800	31.197	17.750	13.447	16.050
282	23.200	10.634	26.802	4.101	10.600	33.800	30.903	17.750	13.153	16.050
288	23.200	10.961	26.897	3.661	10.600	33.800	30.558	17.750	12.808	16.050
294.5	23.200	11.315	26.965	3.255	10.600	33.800	30.220	17.750	12.470	16.050
301	23.200	11.669	26.996	3.030	10.600	33.800	30.026	17.750	12.276	16.050
307	23.200	11.996	27.000	3.000	10.600	33.800	30.000	17.948	12.052	15.852
313	23.200	12.323	27.000	3.000	10.600	33.800	30.000	19.075	10.925	14.725
319	23.200	12.650	27.000	3.000	10.600	33.800	30.000	20.926	9.074	12.874

Figure 4.



EQUIPMENT BAY BASIC LOWER HATCH

Figure 4.7

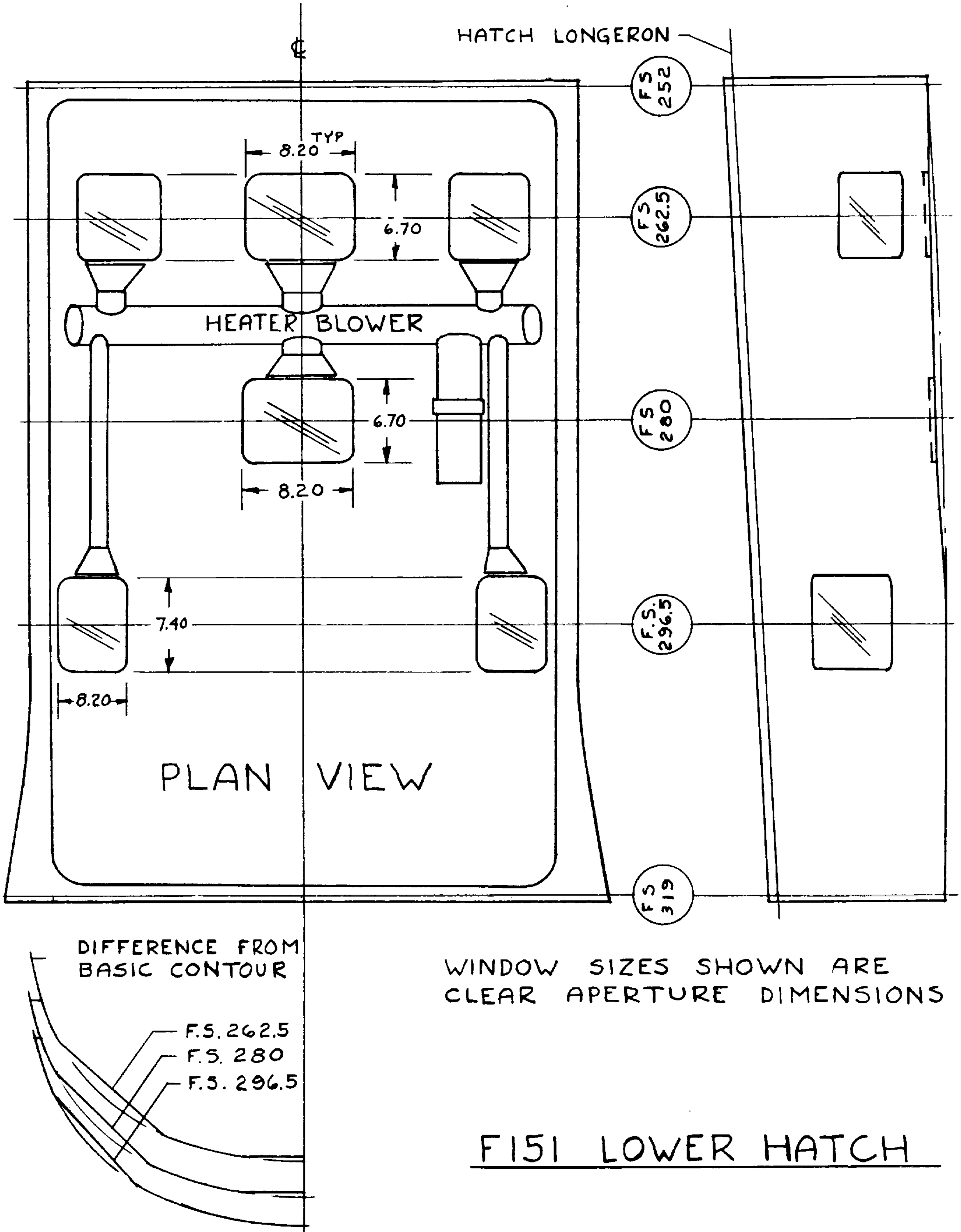

HATCH LONGERON
8.20 TYP
6.70
HEATER BLOWER
6.70
8.20
7.40
8.20
PLAN VIEW
FS 252
FS 262.5
FS 280
F.S. 296.5
FS 319
DIFFERENCE FROM BASIC CONTOUR
F.S. 262.5
F.S. 280
F.S. 296.5
WINDOW SIZES SHOWN ARE CLEAR APERTURE DIMENSIONS
F151 LOWER HATCH

Figure 4.8

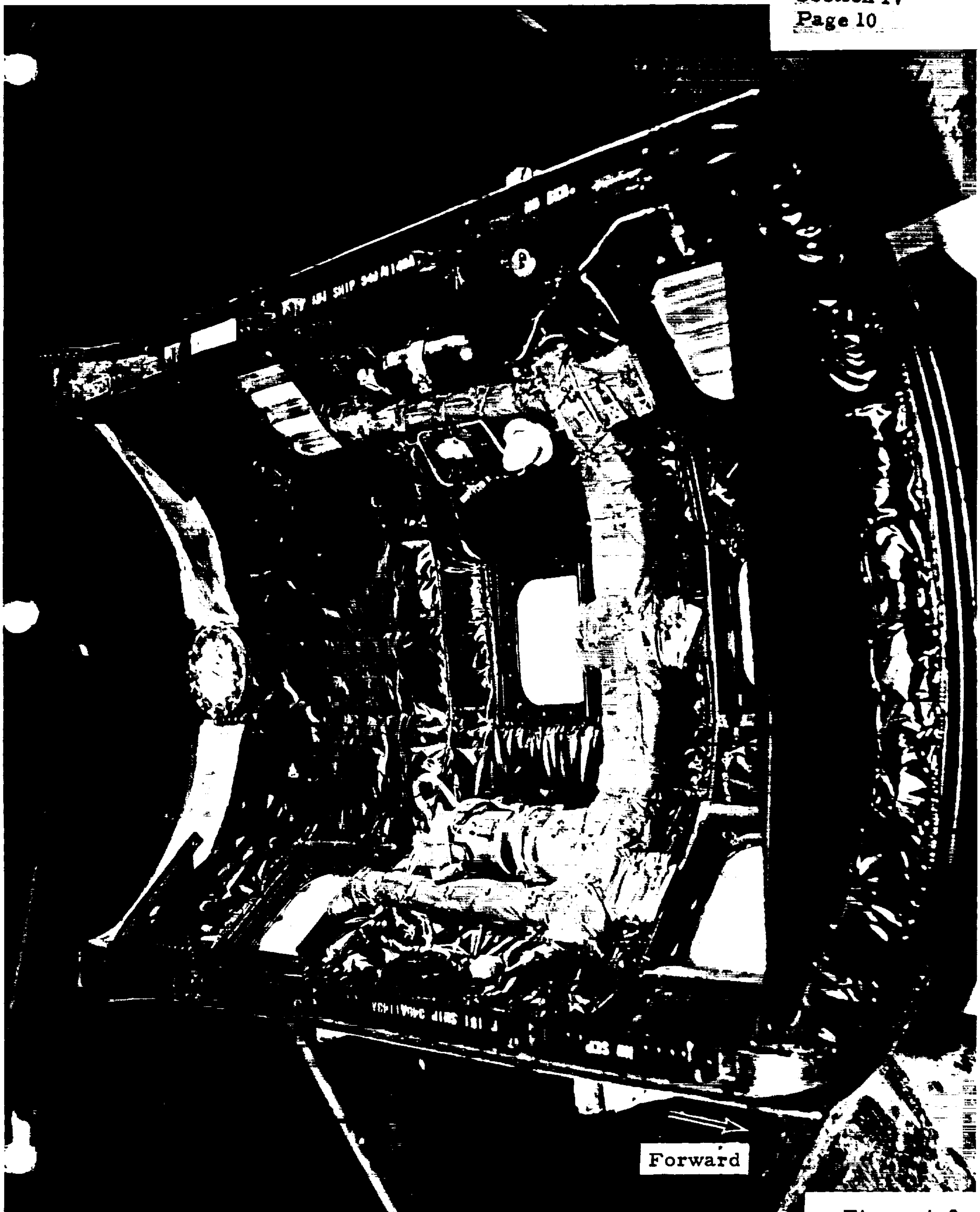
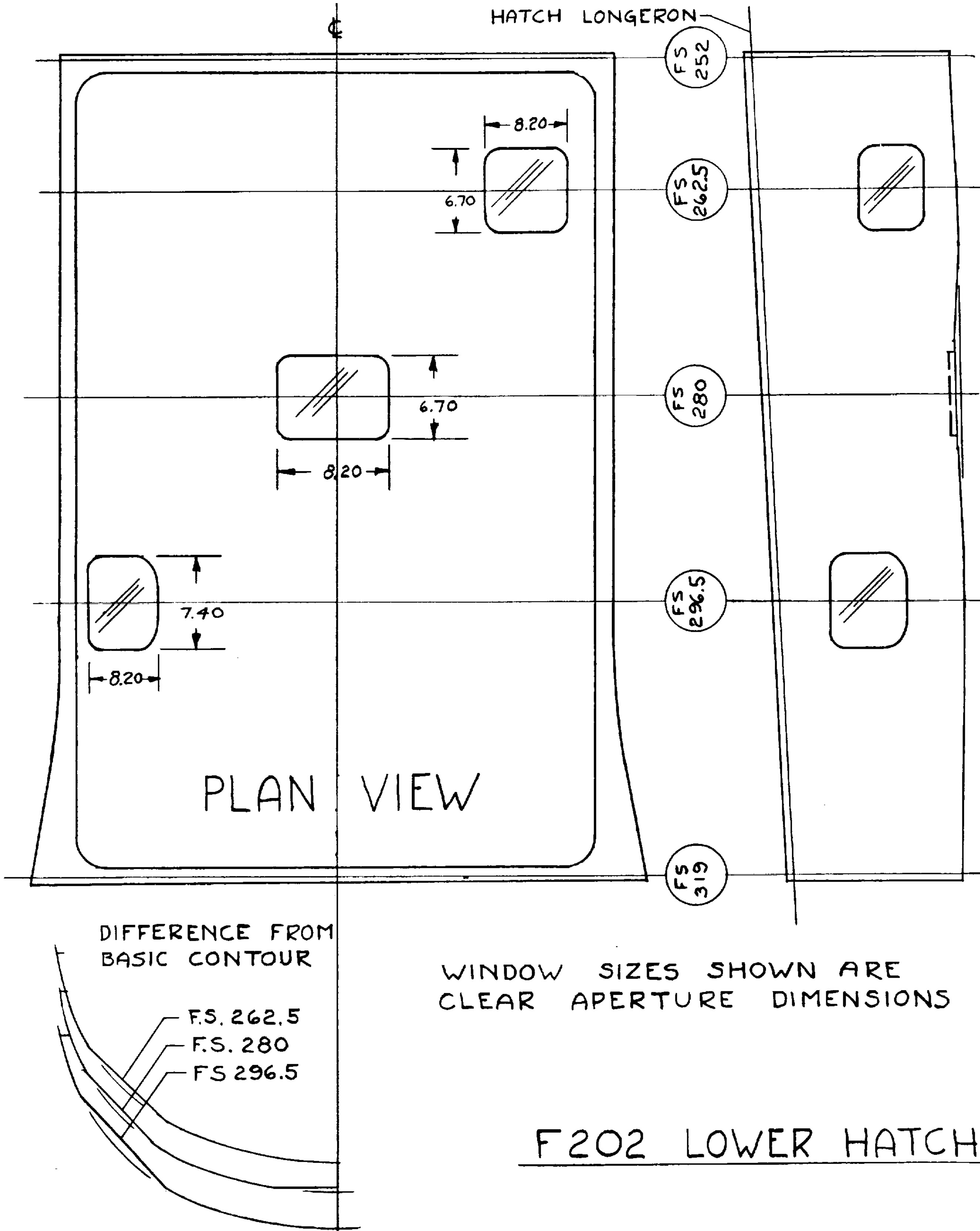


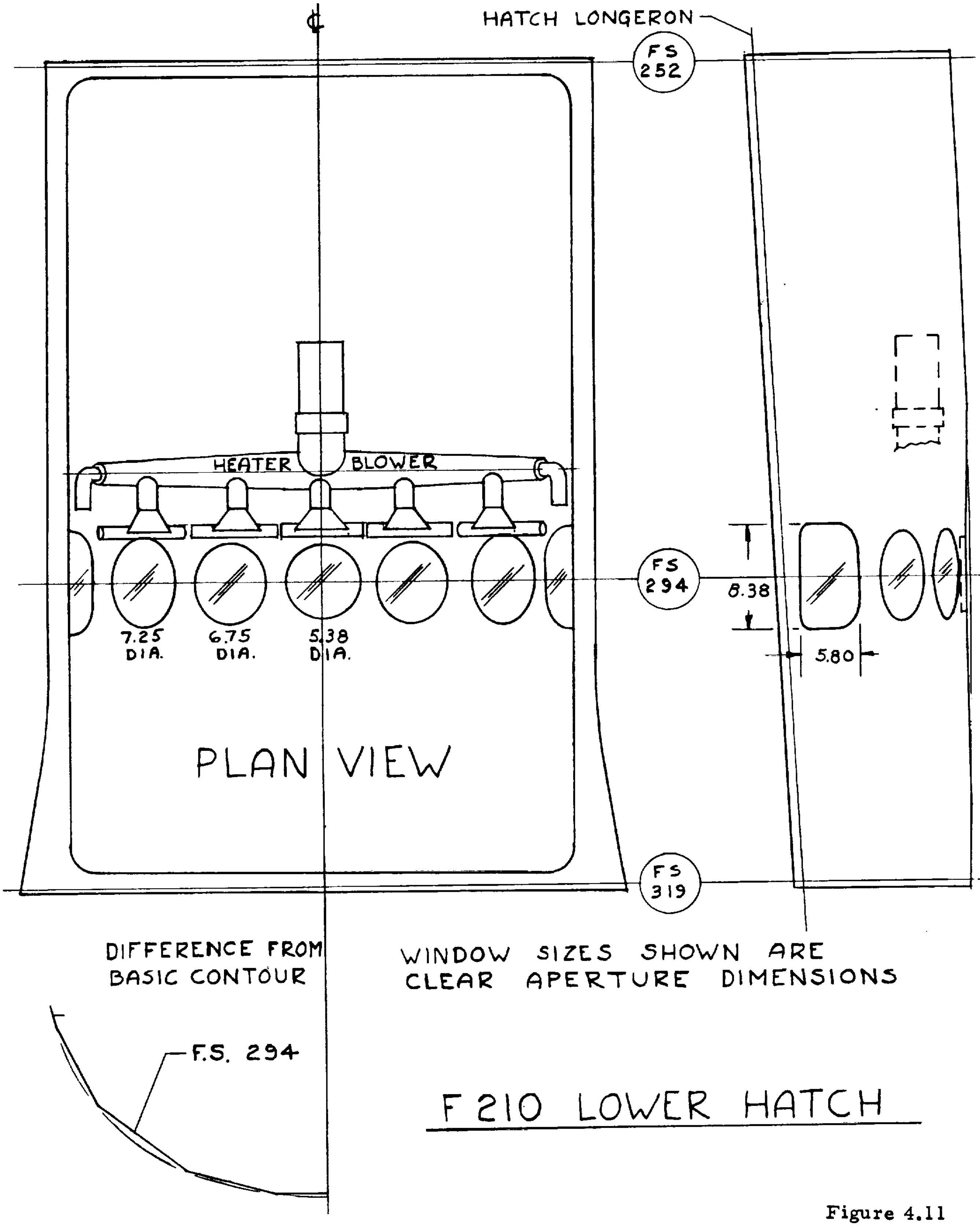
Figure 4.9



WINDOW SIZES SHOWN ARE CLEAR APERTURE DIMENSIONS

F202 LOWER HATCH

Figure 4.10



F 210 LOWER HATCH

Figure 4.11

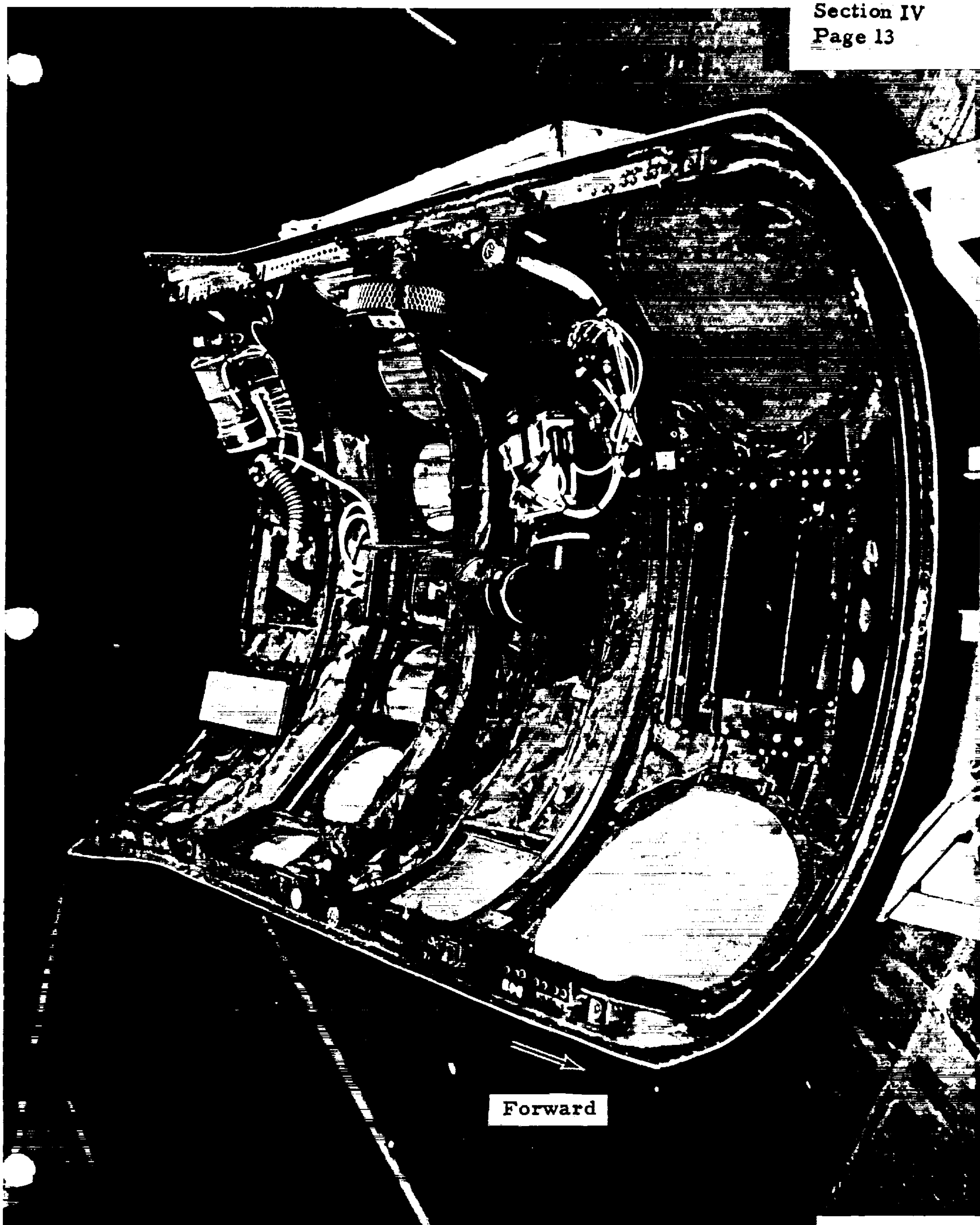
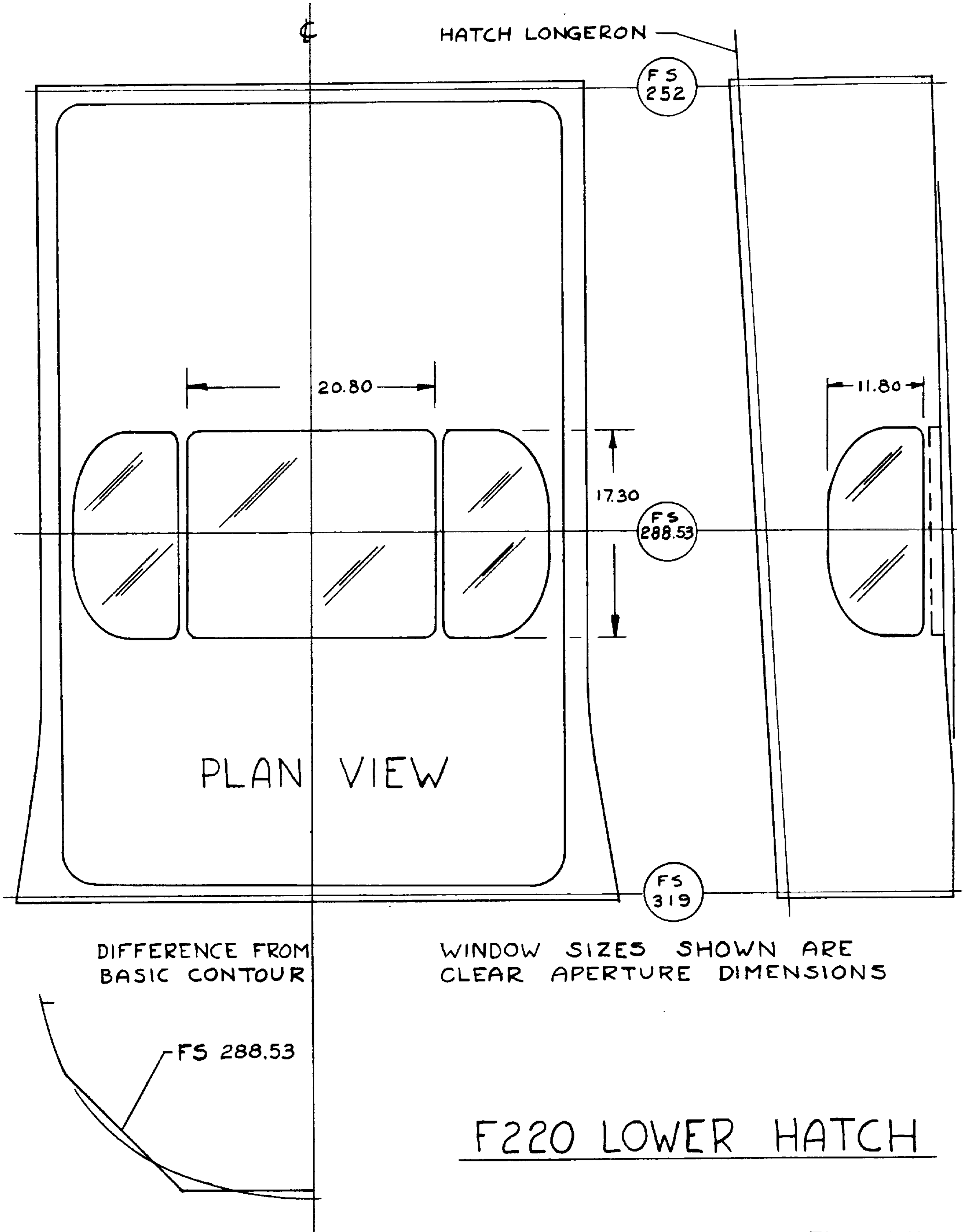


Figure 4.12



F220 LOWER HATCH

Figure 4.13

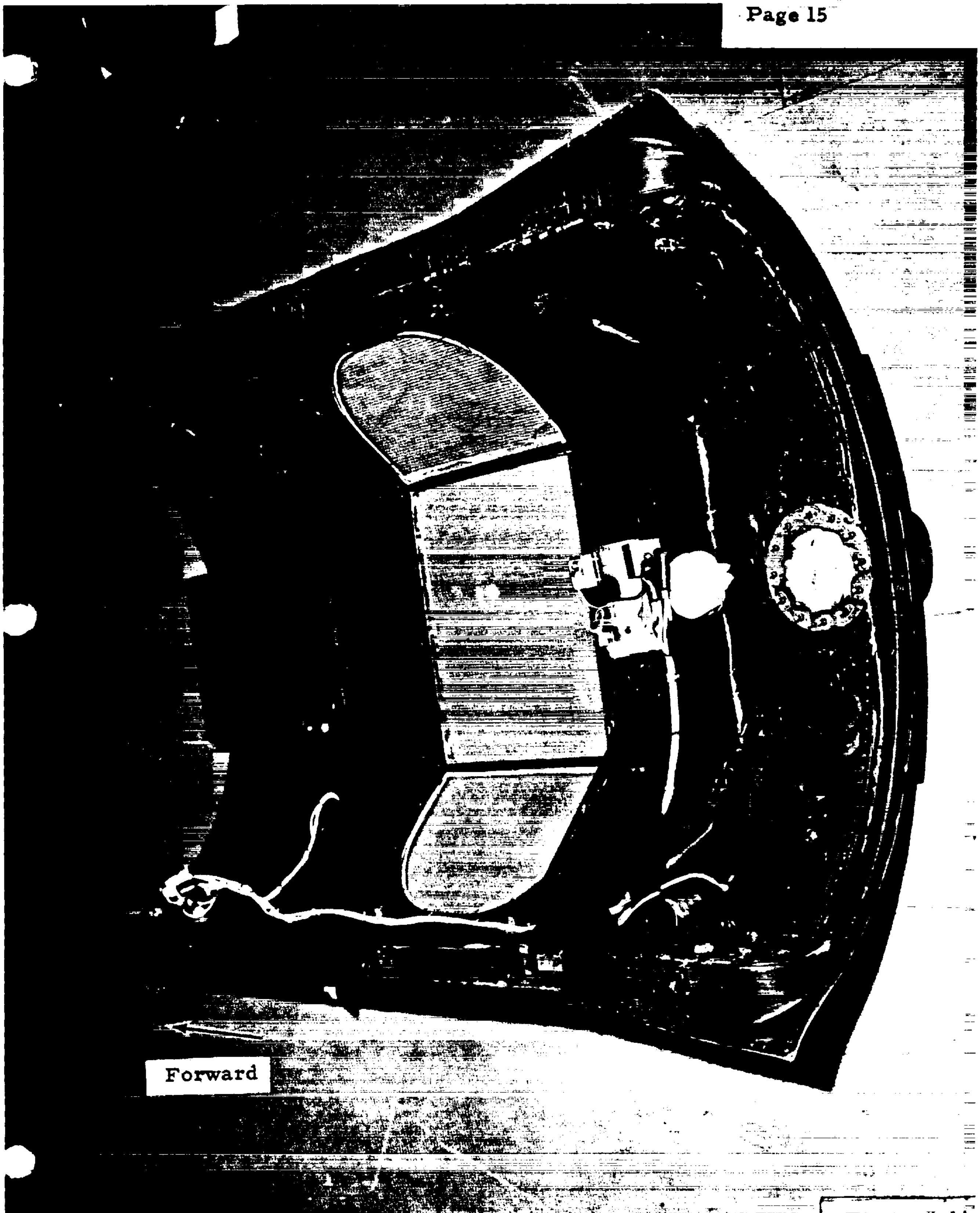


Figure 4.14

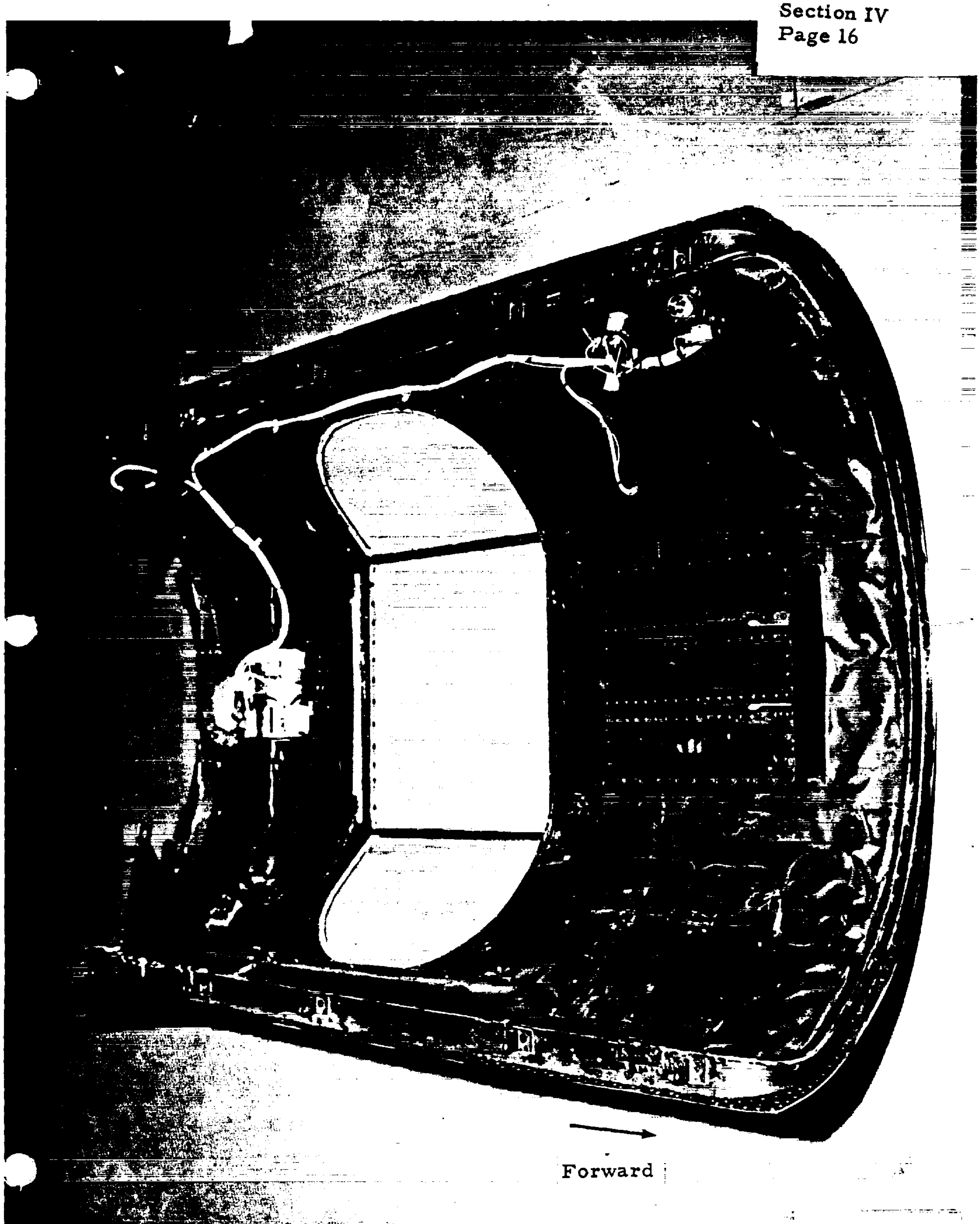


Figure 4.15

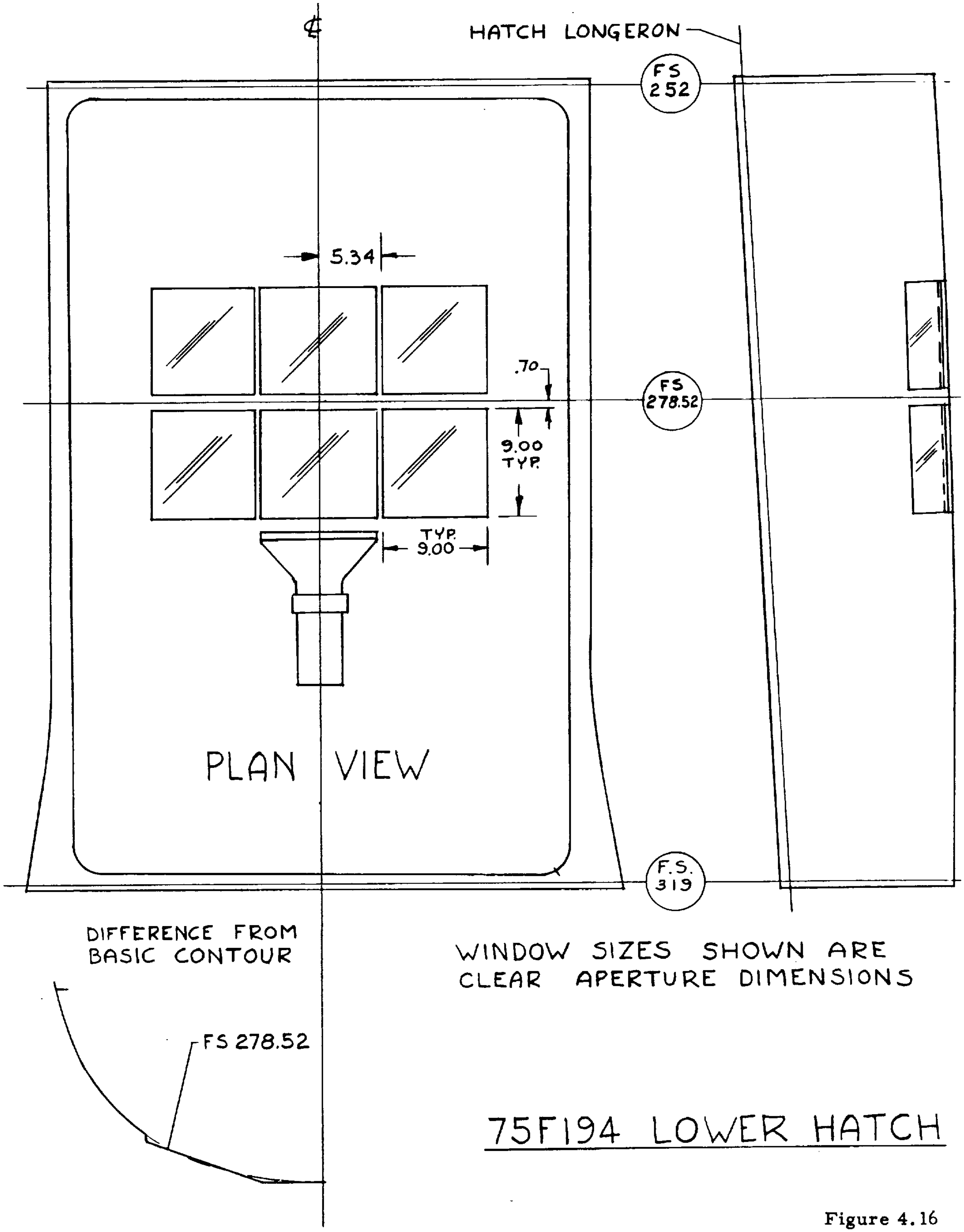

₵
HATCH LONGERON
FS 252
5.34
.70
FS 278.52
9.00 TYP.
TYP. 9.00
PLAN VIEW
F.S. 319
DIFFERENCE FROM BASIC CONTOUR
FS 278.52
WINDOW SIZES SHOWN ARE CLEAR APERTURE DIMENSIONS
75F194 LOWER HATCH

Figure 4.16

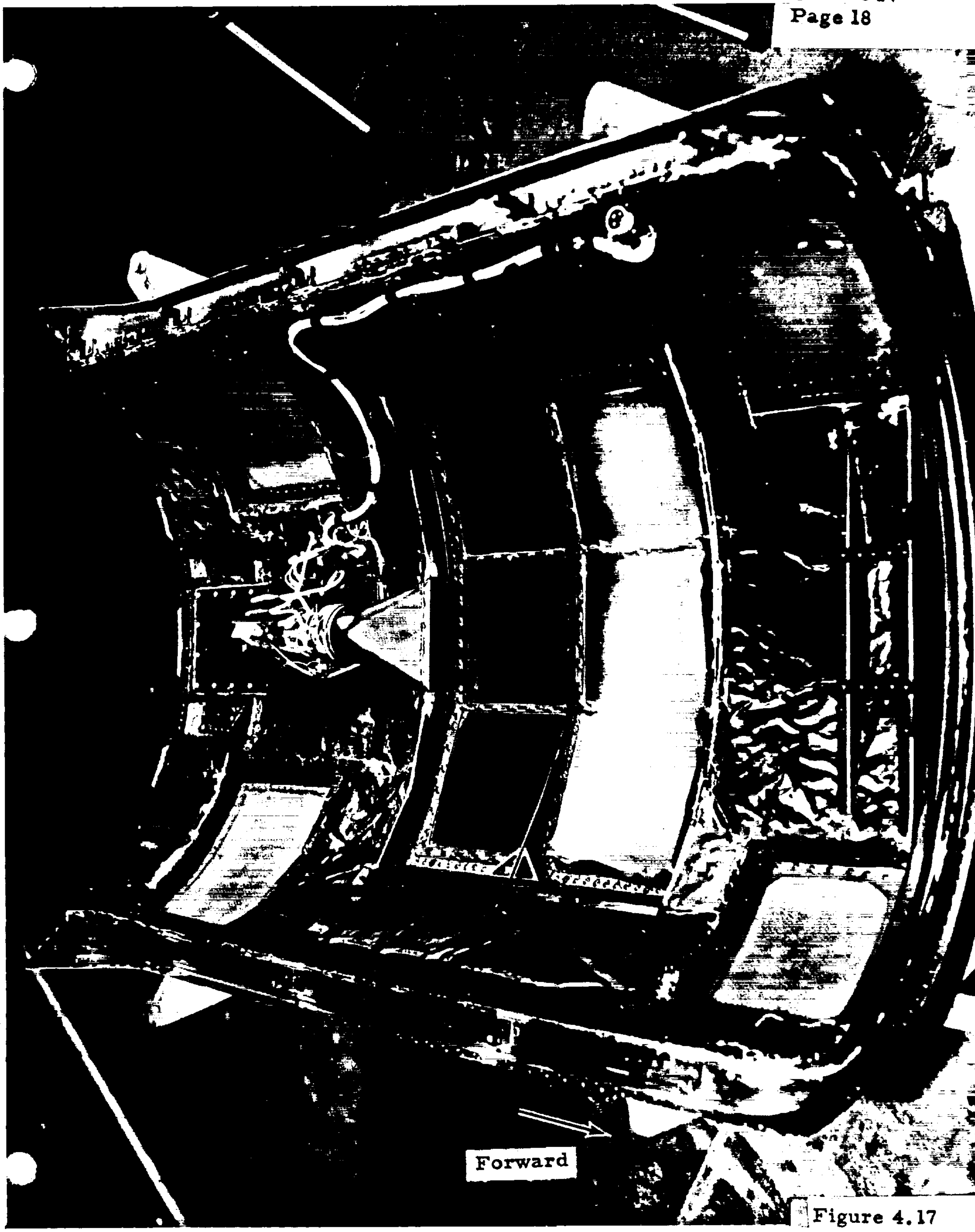
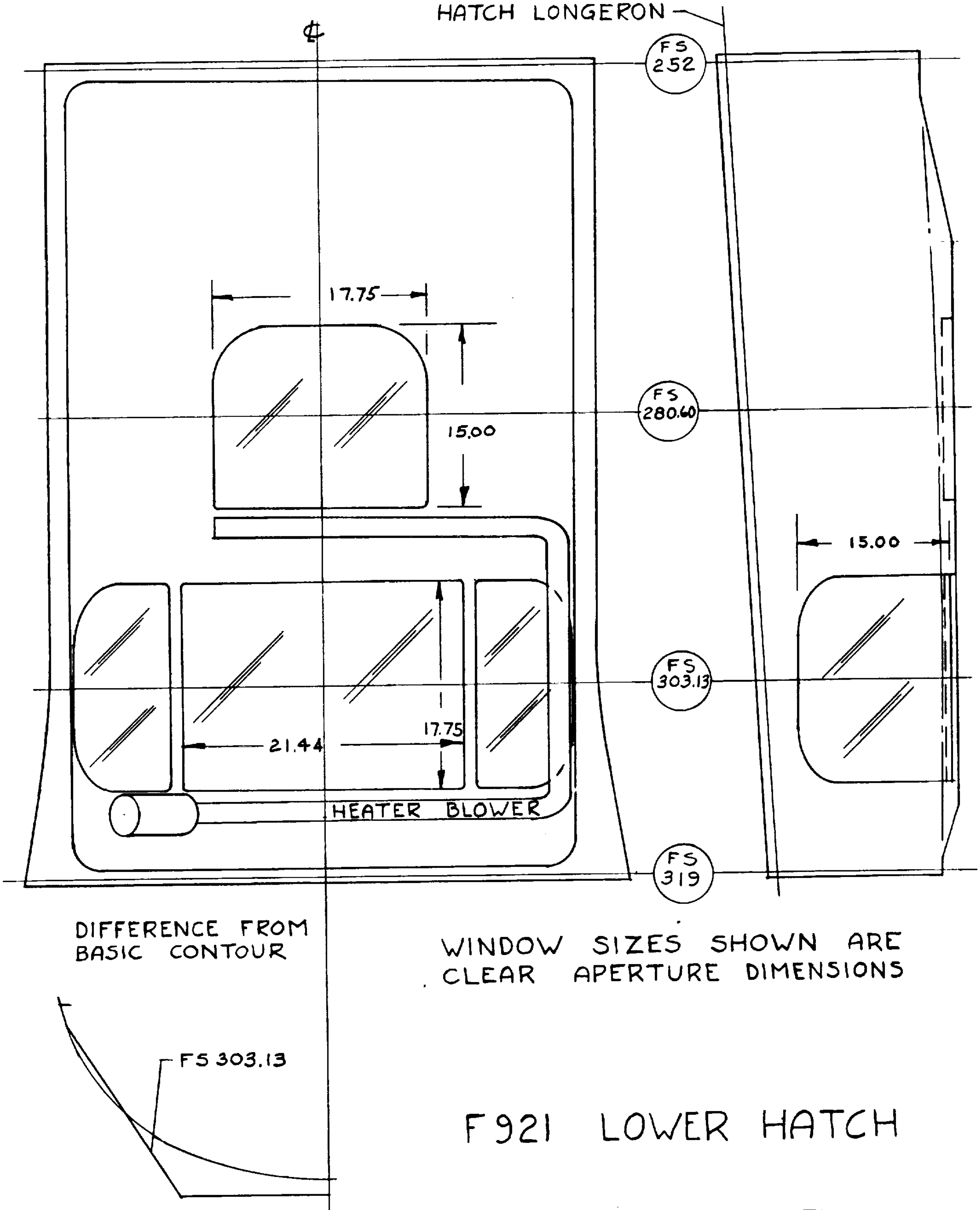


Figure 4.17



F921 LOWER HATCH

Figure 4.18

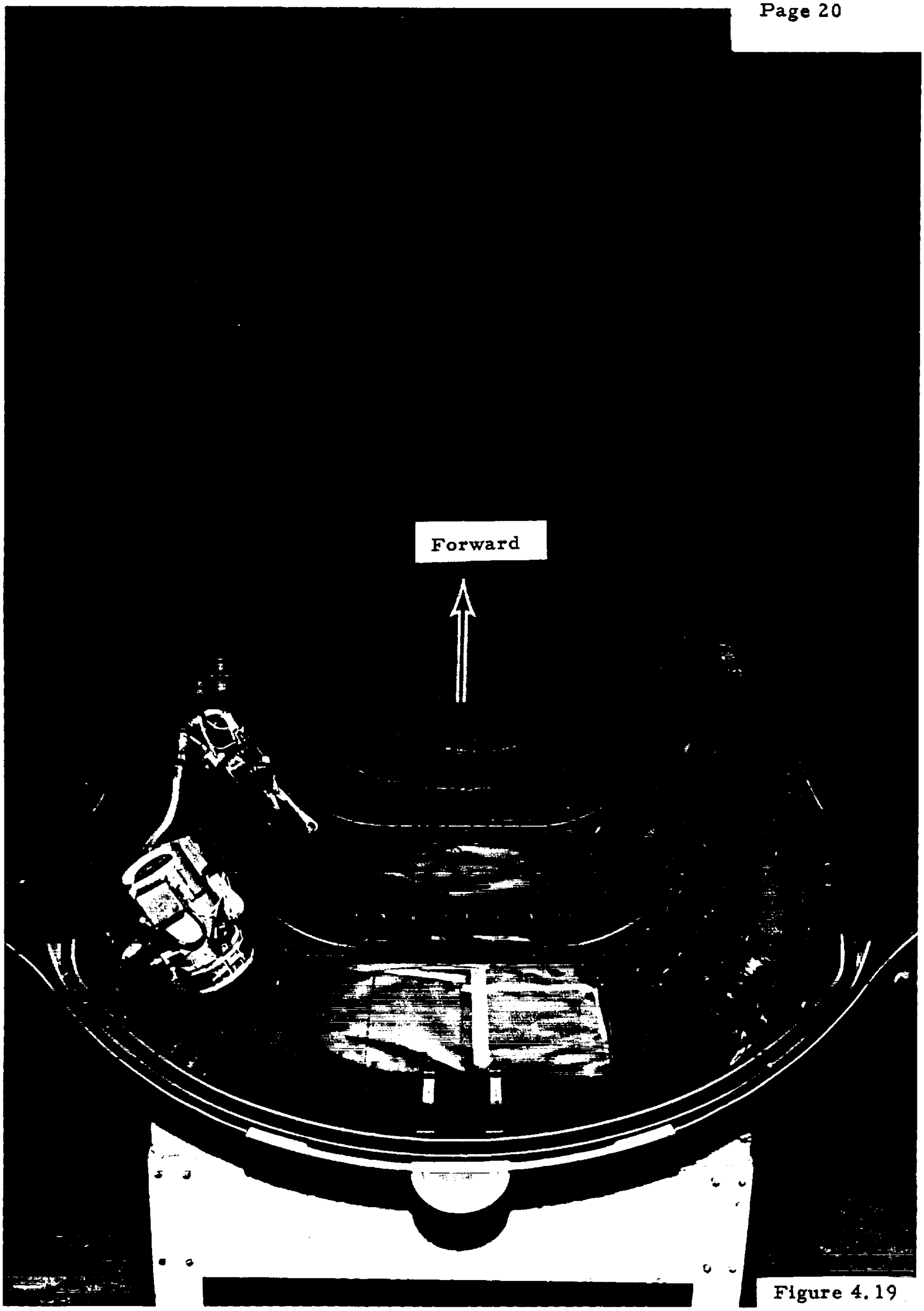


Figure 4.19

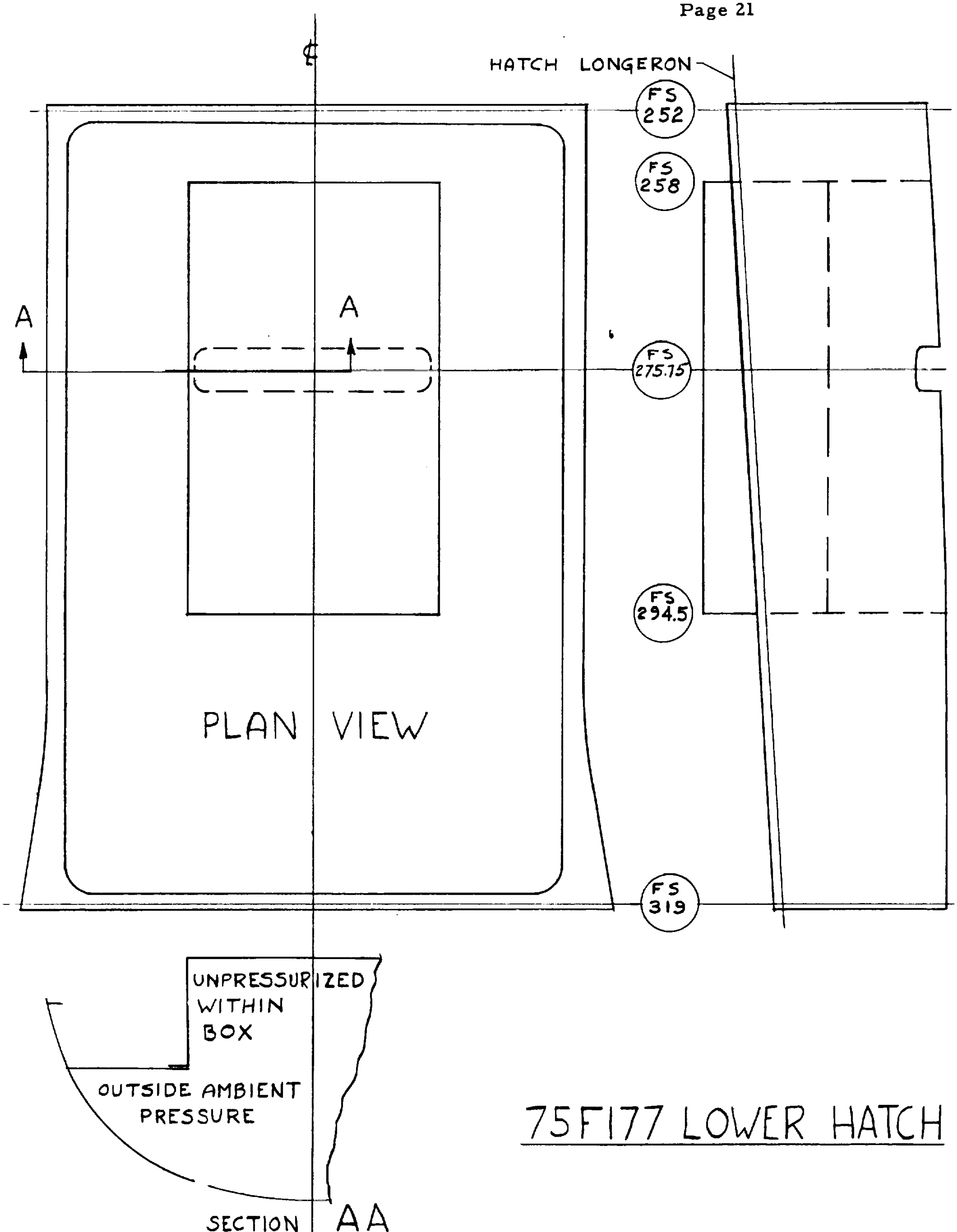
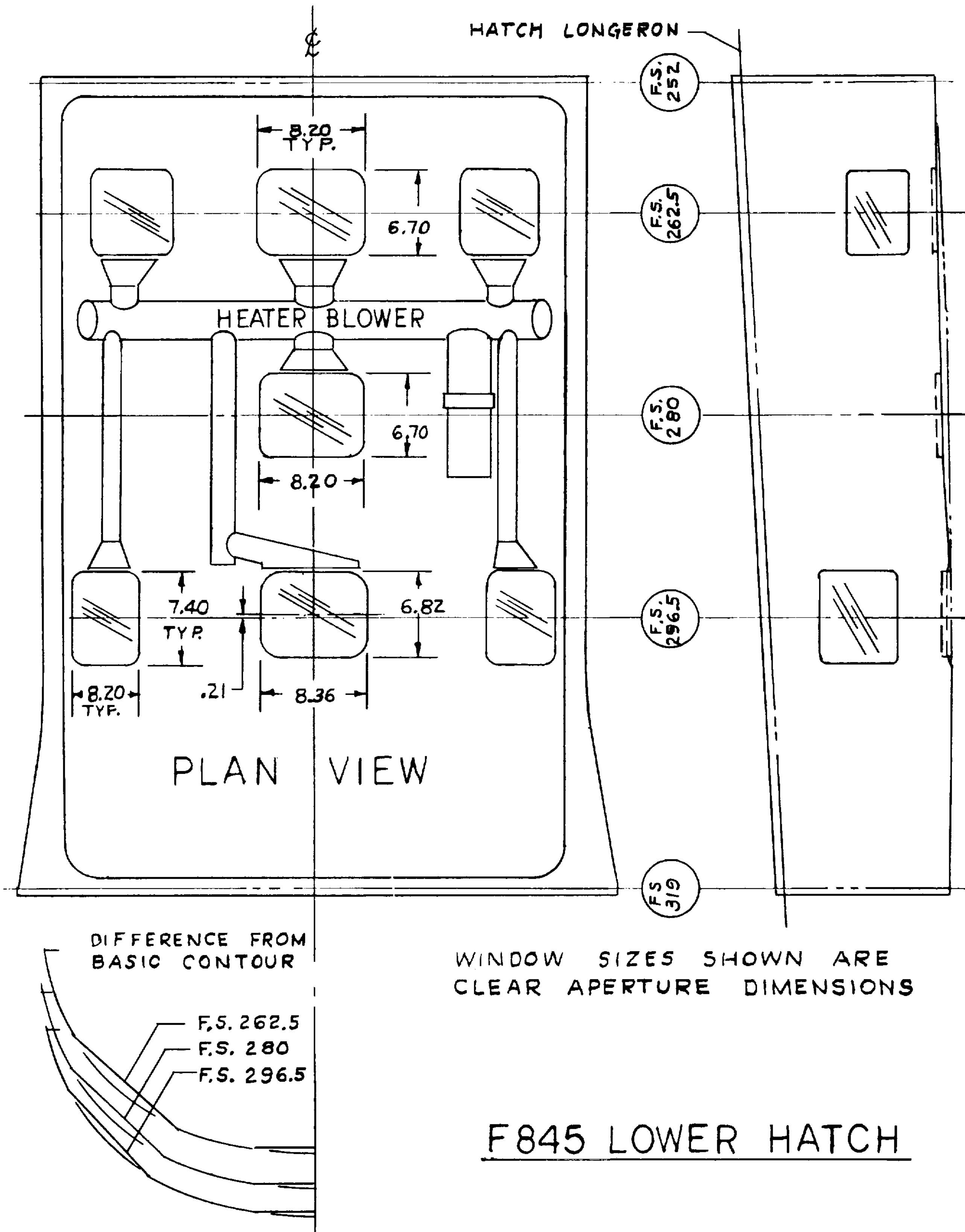

HATCH LONGERON
FS 252
FS 258
A
A
FS 275.15
FS 294.5
PLAN VIEW
FS 319
UNPRESSURIZED WITHIN BOX
OUTSIDE AMBIENT PRESSURE
SECTION AA
75F177 LOWER HATCH

Figure 4.20

Figure 4.21



WINDOW SIZES SHOWN ARE CLEAR APERTURE DIMENSIONS

F845 LOWER HATCH

Figure 4.22

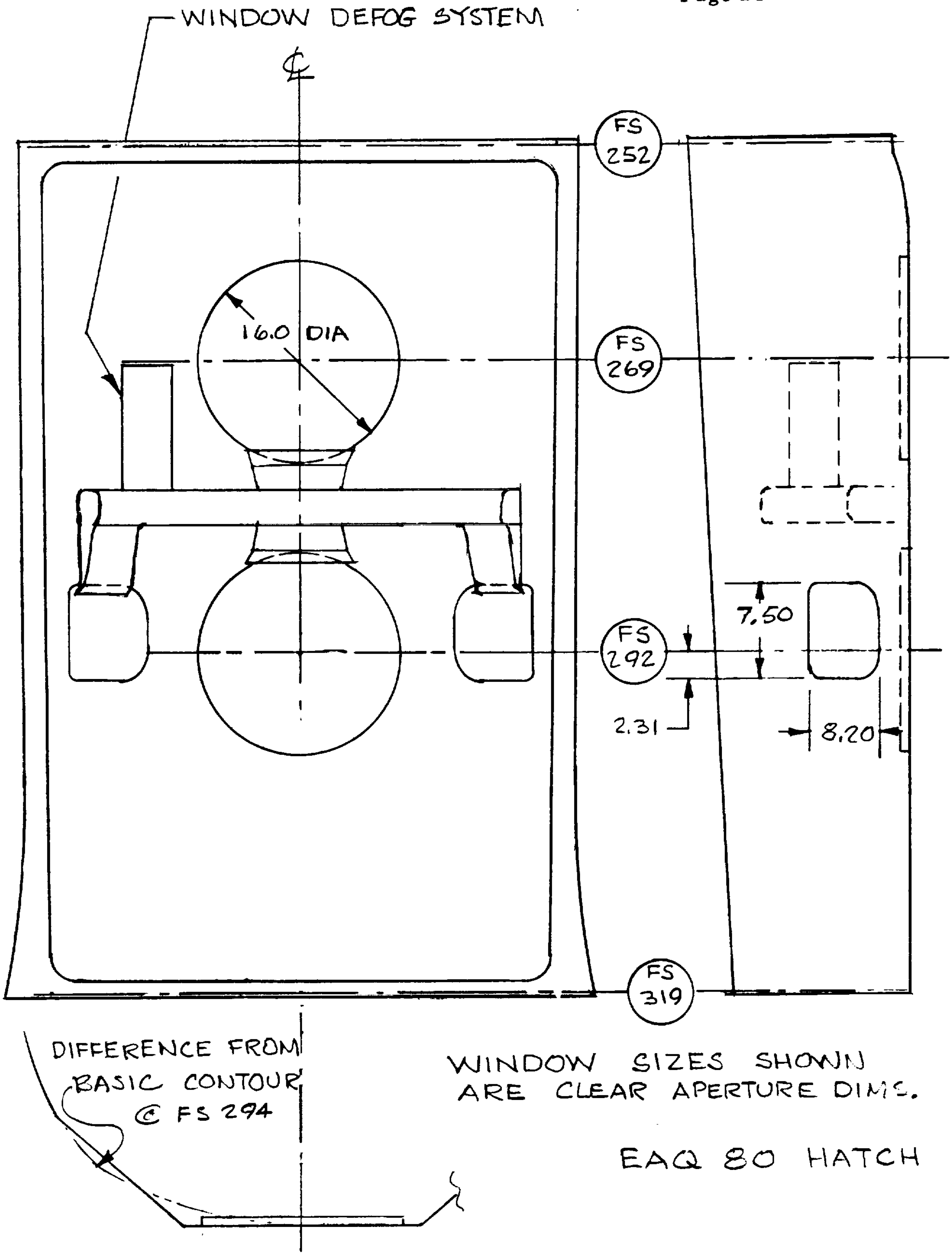

WINDOW DEFOG SYSTEM
℄
FS 252
16.0 DIA
FS 269
7.50
FS 292
2.31
8.20
FS 319
DIFFERENCE FROM
BASIC CONTOUR
@ FS 294
WINDOW SIZES SHOWN
ARE CLEAR APERTURE DIMS.
EAQ 80 HATCH

Figure 4.23

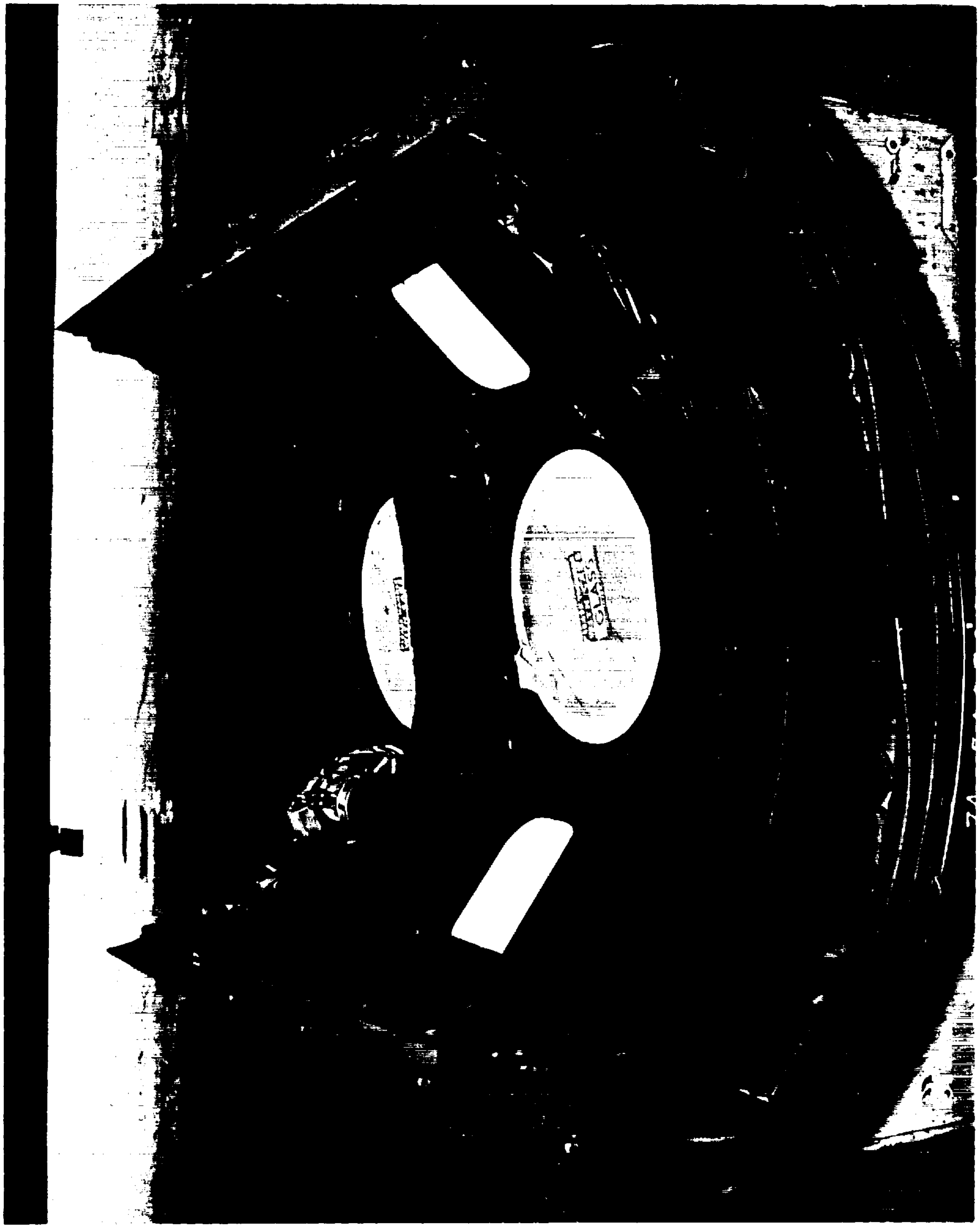


Figure 4.24

SECTION V
EQUIPMENT CONSTRUCTION AND INSTALLATION

The installation of investigators' equipment aboard the aircraft is one of the most demanding and time-consuming aspects of airborne research. Because of familiarity with the ease of travel by commercial airlines, investigators often do not fully appreciate the problems encountered in securing airborne equipment so as to meet standard safety requirements. The specifications, guidelines, and other requirements given in this section are strictly enforced.

5.1 Load Factors - Safety Standards

All equipment, including racks, instruments, pallets, tie-down brackets, must be designed for the load conditions listed below. Consider these factors individually, do not make vector additions.

Load Direction	Ultimate Load Factor
Forward	8.0 (crash condition)
Down	6.0
Up	3.0
Side	2.5
Aft	2.5

ULTIMATE LOAD FACTORS ARE LIMIT LOAD X 1.5

The above requirements are for structural design of the equipment. Permanent set, in any installation components, is not permitted for any load less than 67% of the above factors. It is not required that alignment, calibration, or other instrumental functions be maintained under these load conditions.

5.2 Construction Constraints

The load factor specifications presented in paragraph 5.1 are fully applicable to this section.

5.2.1 Aircraft fasteners and welding

Aircraft structural fasteners (MS or NAS standards) must be used for all structural members. These fasteners must be secured by self-locking nuts or safety wire. Minimum screw size for structural use is .18 dia or bolt size with hex head is .25 dia. In addition to mandatory use for structural members, this type of hardware should also be used for other elements of the equipment whenever possible. A list of approved suppliers of these aircraft structural fasteners is given in Figure 5.1. Data sheets giving detailed nomenclature and engineering specifications for this hardware are available on request from the Airborne Instrumentation Research Branch. Welding of structural members on experimental equipment is acceptable. However, it must be high quality work performed by a welder currently certified to the MIL-T-5021C specification.

5.3 Equipment Bay Racks

Racks to support and/or contain electronics or other equipment generally must be made especially to fit the equipment bay attach points. There are several universal rack designs available which attach to the two aft mounts, F.S. 306.25, BL 15L and BL15R, and the forward mount F.S. 252.6 and BL 0. See equipment bay mount points, Figure 4.5. These racks are capable of supporting up to 500 lbs of experimentors equipment. Two (2) configurations of this rack are shown in Figures 5.2 and 5.3

LIST OF APPROVED SUPPLIERS OF NAS (NATIONAL AEROSPACE STANDARD) HARDWARE

1. STANDARD PRESSED STEEL COMPANY
   2701 HARBOR BOULEVARD
   SANTA ANA, CALIFORNIA 92703

2. KAYNAR & GREER MANUFACTURING COMPANY, INC.
   800 S. STATE COLLEGE BOULEVARD
   FULLERTON, CALIFORNIA 92631

3. VOI-SHAN
   8463 HIGUERA STREET
   CULVER CITY, CALIFORNIA 90230

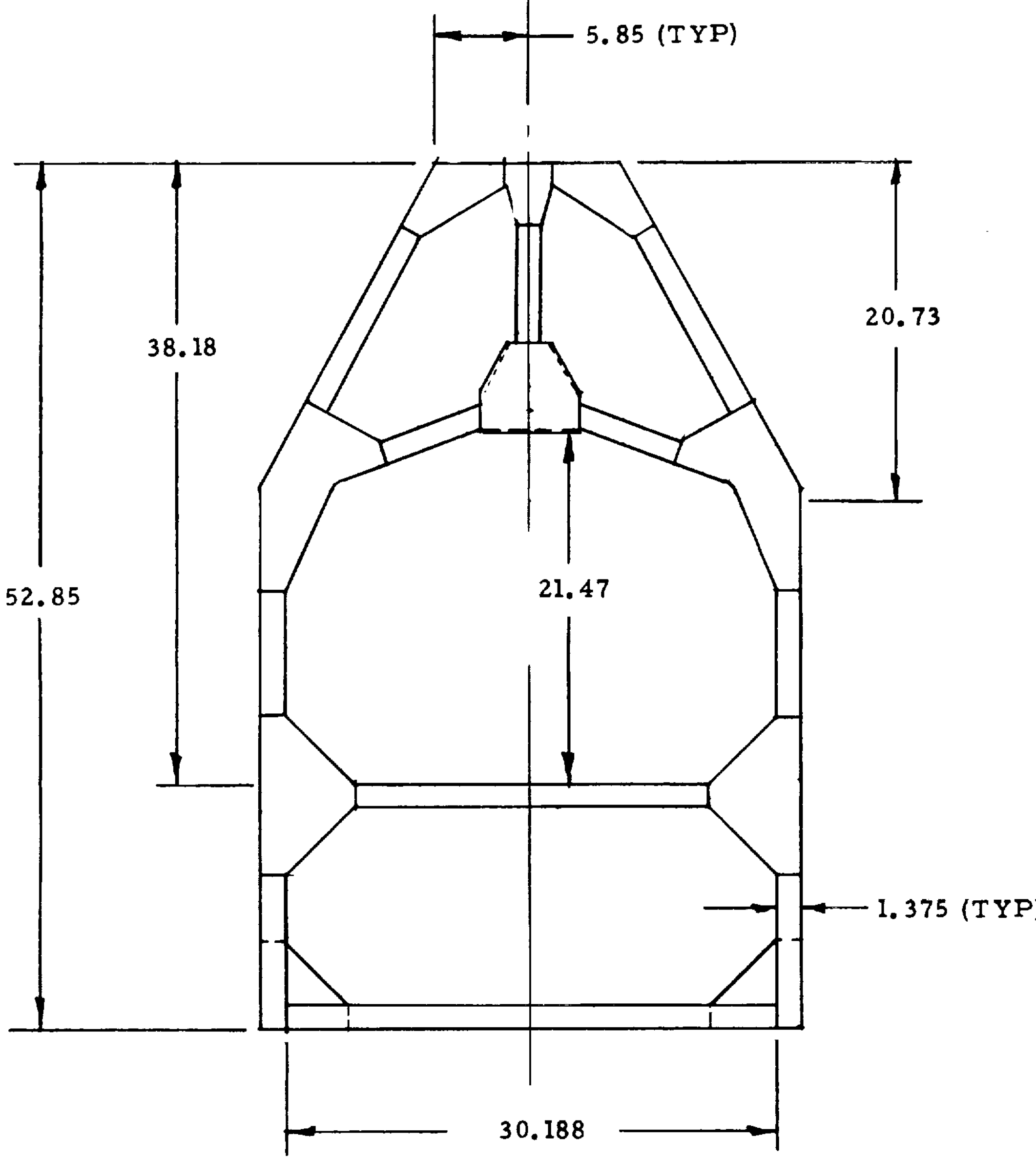
4. ELASTIC STOP NUT CORPORATION
   16150 STAGG STREET
   VAN NUYS, CALIFORNIA 91406

5. HI-SHEAR CORPIRATION
   2600 WEST 247TH STREET
   TORRANCE, CALIFORNIA 90505

6. AIR INDUSTRIES OF CALIFORNIA
   1700 W. 132ND STREET
   GARDENA, CALIFORNIA 90249

FIGURE 5.1

EAQ 1-1 RACK ASSY.

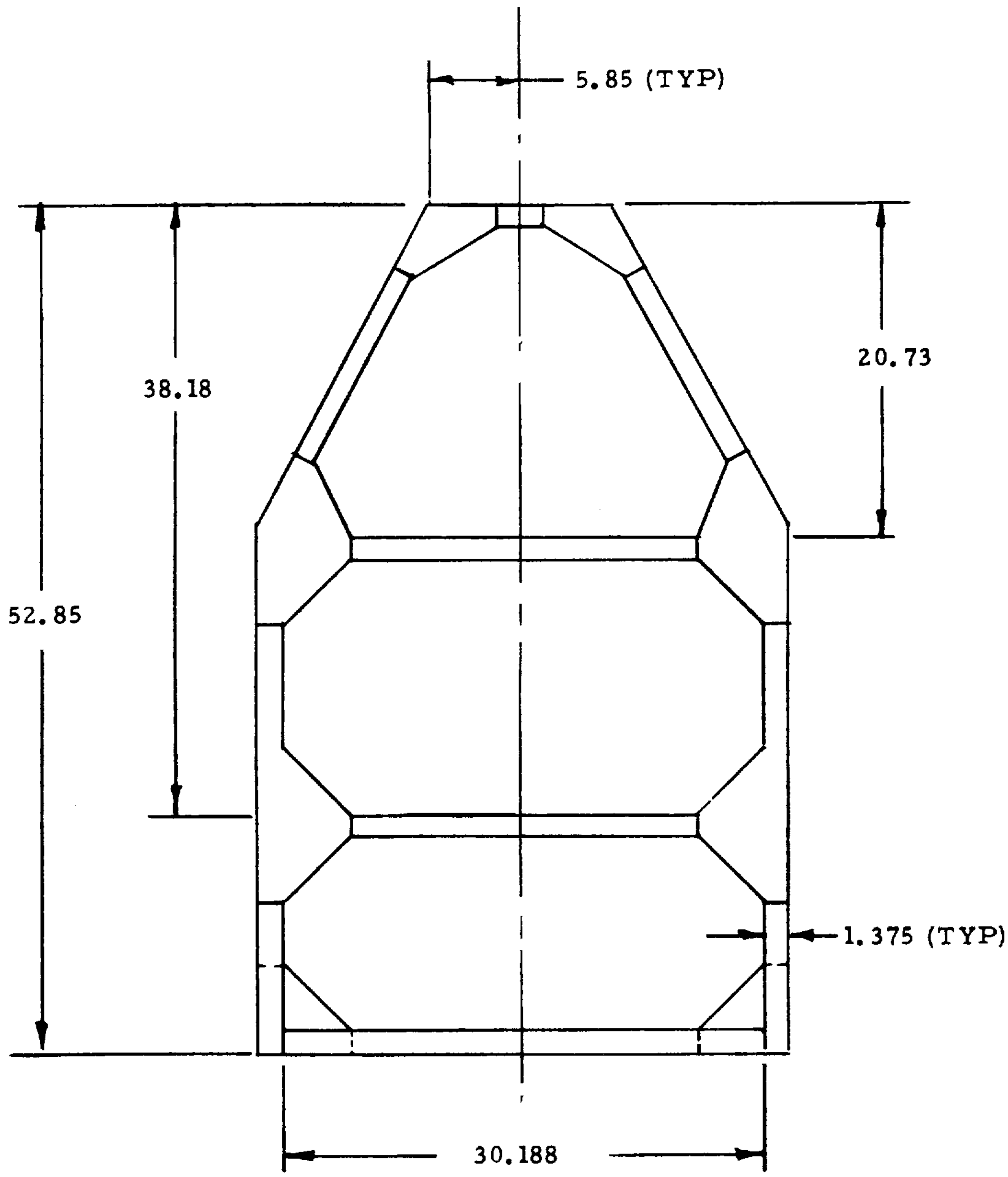


PLAN VIEW

SCALE 1/10

FIGURE 5.2

EAQ 1-500 RACK ASSY.



PLAN VIEW

Scale 1/10

FIGURE 5.3

5.4 Ground Handling Equipment

The Airborne Instrumentation Research Project maintains a limited number of special ground handling equipment items such as lifting slings, power carts, etc. However, the following ground handling equipment, as a minimum, shall be the responsibility of each experimentor in order to assure adequate support of his program:

a. Ground handling dollies or carts
b. Shipping containers
c. Special test equipment
d. Magnetic tape
e. Special gaseous mixtures such as ozone, etc.
f. Cryogenic consumables
g. Test and servicing procedures

Lockheed has designed and is capable of providing any of the above items. With respect to items a and b, any modifications necessary to adapt existing units or drawings to the experimentors equipment shall be accomplished by ADP. In the event that the experimentor chooses to provide the GHE, shipping containers, etc., the designs shall be subject to approval by Lockheed prior to fabrication to preclude possible interference with airplane structure and related support equipment which may be simultaneously used.

SECTION VI

BASIC AIRPLANE

6.1 Configuration Control

The U-2 Program Office has tasked Lockheed with the responsibility of airworthiness and configuration control of the AIRP U-2 aircraft. In order to accomplish this control, the design, fabrication and installation of all supporting structure for the experiment shall be accomplished by Lockheed. The experimentor may, of course, design the experiment instrumentation. But it is necessary for Lockheed to document the configuration of each experiment and accomplish design reviews of the proposed experiment as well as the completed hardware prior to approving the systems as ready for flight.

All changes or modifications to accommodate an experiment will be made by Lockheed Service Bulletins against the existing Lockheed engineering drawings or by adding new ones. Service Bulletins for the AIRP are numbered under a NR series; NR1, NR2, etc. New Lockheed drawings will be added into the existing U-2 drawing structure as required.

6.2 Airplane Wiring Interface

Special trunk lines are permanently installed in the airplane to connect the payload to the control panel in the cockpit and to a power source in the equipment bay. A wiring diagram connecting the experiment to the airplane wiring interface will be prepared by Lockheed for each individual experiment and called out on the Lockheed installation kit drawing.

The constraints of cockpit standardization and isolation of the payload from the airplane power system require that the cockpit control panel and a power junction box be designed, fabricated and in some cases installed by Lockheed utilizing existing or new engineering drawings and NR Service Bulletins, where required.

A wiring diagram connecting the system to the airplane wiring interface will be prepared by Lockheed and called out on the installation kit drawing as described herein. The pilot shall be able to exercise absolute control over electrical power to all experiments during flight and shall be provided the ability to disconnect experiment electrical power at his discretion, in case of an emergency.

6.3 Equipment Bay Packages

This falls into two categories:

6.3.1 Lockheed and Other Agency or Contractor Packages

6.3.1.1 Lockheed Packages

NASA approved packages may be installed in the equipment bay.

Mission kit installations will be made and called out on EAX100 Mission Kit-Instl. Top Assy EAX100 is called out on F50 U-2 Final Assembly. Mission Kit configurations for airplane use, shall be documented in accordance with the Air Force AFTO 95. (Significant Historical Data.)

6.3.1.2 Agency or Contractor Packages

NASA approved equipment bay packages may be installed providing the installation is made within the conditions outlined in paragraphs 6.1 and 6.2. In addition, the final installation shall be approved by Lockheed Engineering prior to the first flight.

When the installation is ready for flight, an installation kit drawing will be made by Lockheed and called out on EAX100 Mission Kit-Instl. Top Assy EAX100 is called out on F50 Final Assembly. Mission Kit configurations for airplane use, shall be documented in accordance with the Air Force AFTO 95. (Significant Historical Data.)

6.4 Airplane Installations Other Than in the Equipment Bay

This outlines installations which are located other than in the equipment bay and falls into two categories:

Lockheed and Other Agency or Contractor Installations

Airplane changes, modifications or additions required because of Lockheed or other agencies installations shall be made by Lockheed only per NR Service Bulletins. New installations not falling under the Mission Kit category will be called out on EAQ50, which, in turn, will be called out on F50 U-2 Final Assembly. Airplane configurations shall comply with applicable portions of the following three inspection outlines:

a. Lockheed ADP Inspection Job Instructions

b. AFTO 95 (Significant Historical Data)

c. U-2 Maintenance Manuals

6.4.1 Lockheed Installations

NASA approved installations may be installed on the airplane in accordance with paragraphs 6.1 and 6.2.

6.4.2 Agency or Contractor Built Experiments

NASA approved agency or contractor built experiments may be installed on the airplane as outlined in paragraphs 6.1 and 6.2. Steps and methods required for fabrication, assembly and inspection follow. The final experiment design shall be approved by Lockheed Engineering prior to the first flight.

6.4.2.1 Design Stage

A review with Lockheed, NASA and other parties involved will determine to what extent Lockheed review of stress, aerodynamics, etc., will be required.

6.4.2.2 Engineering Drawings

Drawings shall be made by the experimentor defining each part either in detail or on an assembly drawing. A top drawing of the final experiment configuration will define what is required for the airplane installation. This top drawing will be called out on mission kit installation drawing prepared by Lockheed and will become a part of the U-2 drawing structure. Any changes to the drawings shall be coordinated with Lockheed prior to accomplishing the change.

6.4.2.3 Detail Part Manufacture

a. Part Fabrication

A simple breakdown showing detail part fabrication steps for each part shall be provided with the assembly for inspection purposes.

b. Sheet Metal Parts

All aluminum sheet metal parts shall be made of clad material. This does not include welded assemblies extrusions or machine fittings. No magnesium material will be permitted. Where conditions permit, stainless steel and carbon steel may be used.

c. Machine Parts

Detail breakdown for machine parts is under 6.4.2.8.

d. Welded Assemblies

All welded assemblies shall include welding certifications. The welder accomplishing the work shall be currently certified to the MIL-T-5021C Specification and such certification shall be provided to Lockheed in writing.

6.4.2.4 Materials

Approved materials for use in part fabrication:

6.4.2.4.1 Aluminum

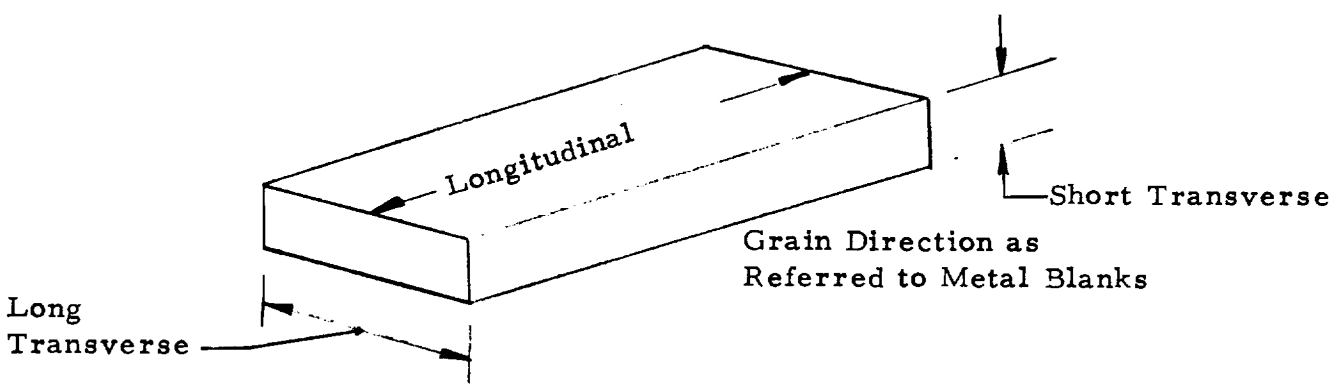
a. Sheet Stocks .005 through .190 thick

2024	- T3	Clad
	- T42	Clad
7075	- T6	Clad
	- T76	Clad

b. Machine Parts

2024	- T351	Plate
	- T851	Plate
7075	- T651	Plate
7075	- T351	Plate
2024	- T4	Bar
2024	- T351	Bar
7075	- T73510	Bar
7075	- T76510	Bar

Engineering drawings, on machine parts, shall specifiy grain direction where loads are structurally critical.



Grain Direction as Referred to Metal Blanks

c. Extrusions

2024 - T4
2024 - T3510
2024 - T3511
7075 - T6
7075 - T76

d. Weldable Aluminum (Fusion Welding)

6061 - T4
6061 - T6

6.4.2.4.2 Steel

a. 301 Cres Sheet .012 through .190

1/4 hard

1/2 hard

Full hard

b. 302 Cres Sheet annealed

c. 4130 Sheet Condition N .062 through 1.500

d. 4130 Plate Heat Treated .062 through .625

e. 4130 Plate Condition A

6.4.2.5 Minimum Bend Radius (Sheet Metal)

a. Aluminum:

Material	Sheet Thickness .016	.020	.025	.032	.040	.050	.063	.071	.080	.090	.100	.125
2024-T3 2024-T42	.06	.06	.09	.09	.12	.16	.22	.25	.31	.38	.44	.56
7075-T73510 7075-T76510	.09	.09	.12	.16	.19	.22	.28	.38	.38	.44	.62	.75

b. 300 Series Stainless Steel:

Material	Sheet Thickness .016	.020	.025	.032	.036	.040	.045	.050	.063	.071	.080	.090	.112	.125
Annealed	.03	.03	.03	.06	.06	.06	.09	.09	.09	.12	.12	.12	.16	.19
1/4 Hard	.06	.06	.06	.06	.09	.09	.09	.12	.12	.16	.16	.19	.22	.25
1/2 Hard	.06	.06	.09	.09	.12	.12	.12	.16	.16	.19	.25	.25	.31	.38
Full Hard	.06	.09	.12	.12	.16	.16	.19	.22	.25	.31	.31	.38	.44	.50

c. Carbon Steels:

Material	Sheet Thickness .016	.020	.025	.032	.036	.040	.045	.050	.063	.071	.080	.090	.112	.125
1020	.03	.03	.03	.03	.06	.06	.06	.06	.06	.09	.09	.09	.12	.12
4130 4140	.03	.03	.03	.06	.06	.06	.06	.09	.09	.12	.12	.16	.16	.19

6.4.2.6 Heat Treatment

Aluminum:

a. If there is reason to obtain material in the unheat treated condition, it shall be heat treated into the condition shown:

As Received	Final Heat Treated Condition
2024-0	T42
7075-0	T6
6061-0	T6

b. Machine Parts:
Heat treat only when added strength is required.

As Received	Heat Treated Condition
T351	T851

c. Welded Assemblies:
Welded and brazed assemblies shall be designed for "as welded" and "as brazed" condition unless high mechanical properties are required for structural reasons. It should be so stated on the engineering drawing. (See paragraph 6.4.2.3d for welder certification requirements.)

6.4.2.7 <u>Detail Part and Assembly Processing</u>

a. Cleaning, heat treat, Rockwell, aging, etc., shall be accomplished per standard aircraft procedures. Specific processing questions should be referred to Lockheed for detail breakdown.

6.4.2.7 Detail Part and Assembly Processing (Continued)

b. All aluminum detail parts shall be painted with zinc chromate primer or equivalent. Thus, all exposed and faying surfaces of each detail part shall be painted. Individual paint requirements after the primer are up to the agency building the assembly.

c. All carbon steel parts shall be cadmium plated. Individual paint requirements after the cadmium plating are up to the agency building the assembly.

d. Stainless steel parts need not be painted; individual paint requirements, however, are up to the agency building the assembly.

6.4.2.8 Machine Parts

It is expected that the majority of machine parts will be of aluminum. Other materials may be used only when specifically approved. Engineering drawings shall define the following:

a. Material

b. Internal Corner Radius

Sharp corners create stress concentrations so the radius should be as generous as is practical.

c. Surface Roughness

Surface roughness of 250 is normally acceptable for structural requirements. For highly loaded structural parts, a lower surface roughness number is required. The lower the number, the smoother the surface. Normal machine cuts of flycut, turn, bore, spotface, drill, mill, and broach produce surface roughness of 250 or lower.

6.4.2.8 Machine Parts (Continued)

d. Grain Direction

When machine parts are structurally critical, the grain direction shall be defined as outlined in 3.2.4.1b.

e. Dye Penetrant Inspect

This is a means of inspection on machine parts to check for minute cracks.

f. Thin or feather edges shall be avoided.

6.4.2.9 Assemblies

Types of assembly attachments consist of rivets, bolts, screws and welded.

a. Aluminum Rivets Available Are:

MS20426 (Flush)
MS20470 (Button Head)

Blind attachments should be used only when necessary. Available aluminum blind rivets are:

NAS1739E (Flush)
NAS1738E (Button Head)
NAS1398D (Button Head)

b. Bolts

The smallest structural bolt, with hex head permissible is 1/4 diameter and must be of aircraft quality such as NAS, MS, or equivalent.

6.4.2.9 Assemblies (Continued)

c. Assembly Requirements

Minimum edge distance for rivets, screws and bolts is twice the diameter of the attachment from the center to the edge.

Screw or bolt hole size except when closer fits are required for functional or structural reasons are as follows:

Screw Size	Structural Hole	General Structure Hole	Full Float Plate Nut
3/16	.193	.198	.249
	.199	.204	.255
1/4	.251	.260	.311
	.258	.267	.318
5/16	.315	.327	.374
	.322	.334	.381

d. All screws or bolts shall be locked in place by stop nuts, safety wire or cotter pins. Tapped holes may be used except in aluminum where rosan inserts or equivalent should be used. Screws in tapped holes shall have heads safety wired. Screws with nylon inserts may be used when flush attachments are required.

e. Bolts or screws shall be used for tension attachments.

f. A washer will always be used under a nut. A washer will always be used under a bolt or screw head, except flush, when it is turned into a captive nut or tapped hole.

6.4.2.9 Assemblies (Continued)

g. Bolts or screws shall have grip lengths such that threads bearing in structural members will be avoided.

6.5 Detail Parts and Assembly Shop Inspection

Agency or contractor-made details, assemblies and installations are subject to applicable portions of the following three inspection outlines prior to installation in the airplane and/or first flight:

a. Lockheed ADP Inspection Job Instructions

b. AFTO 95 (Significant Historical Data)

c. U-2 Maintenance Manuals

6.6 High Pressure Bottle Installations

It is permissible to carry in high pressure bottles up to 2000 psi, gaseous nitrogen or helium but not oxygen or hydrogen due to the extreme fire hazard potential. Available space and system weight are the only limitations for bottle size.

6.6.1 Bottle Design Specification

All bottles shall comply with specification MIL-C-7905D or equivalent. Compliance is required with Interstate Commerce Commission (ICC) requirements which is part of the above specification and controls the manufacturing of any high pressure vessel.

6.6.2 Pressure Regulator

All prsssure bottle systems shall have a pressure regulator with a blowout disk or pressure relief valve to prevent overpressurization. It is not required to vent the discharge overboard. A deflector may be required, depending on the location of the blowout device.

6.6.3 Cryogenic Cooling Devices (Dewars, etc.)

It is permissible to carry cryogenic cooling devices such as dewars, bottles, etc., using liquid nitrogen or liquid helium. The experimentor should be advised that the equipment bay pressure altitude will vary from ground ambient to as high as 35,000 ft pressure altitude during accomplishment of a mission and his cooling device should be designed accordingly.

6.6.4 Safety Precaution Requirements

The system shall be so designed to preclude the possibility of accidental spillage of liquids during the installation into the airplane of an approved system. Consideration shall also be given to the airplane attitudes encountered during climbout (approximately 60° noseup) and descent (approximately 20° nosedown) to assure that liquids are not subject to spillage. Under no circumstances shall liquid nitrogen or liquid helium be allowed to be discharged inside the equipment bay.

6.6.5 Design Approval

When any pressure system utilizing a liquid or high pressure gaseous system is required for a given experiment, drawings outlining bottles, pressure regulators, blowout disks, line sizes, line pressures, etc., shall be made available to the Airborne Instrumentation Research Program (AIRP) office at NASA Ames and to Lockheed prior to final design and fabrication for approval authority.

6.6.6 Toxic Gasses

The use of any toxic gas, including, chlorine, ozone and nitric oxide shall require specific approval, in writing, from the U-2 Project Manager at NASA Ames and Lockheed ADP prior to the design and fabrication of experiment hardware.